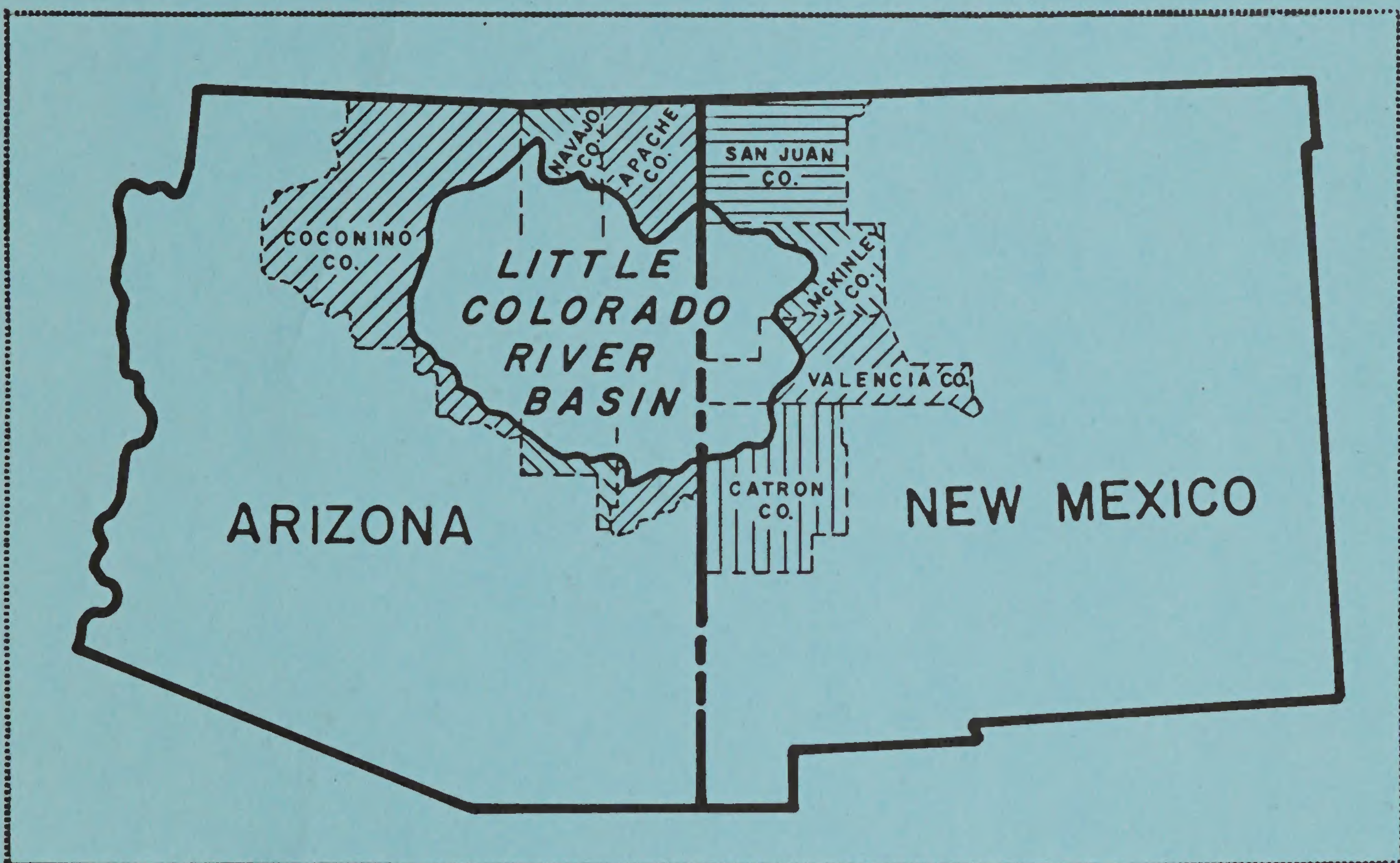
LITTLE COLORADO RIVER BASIN
ARIZONA-NEW MEXICO

APPENDIX III
EROSION & SEDIMENT AND FLOODING



U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ECONOMIC RESEARCH SERVICE
FOREST SERVICE

In cooperation with the states of
ARIZONA AND NEW MEXICO

December 1981

The "Erosion and Sediment, and Flooding" Appendix is one of four (4) such appendices which supports and supplements a "Summary Report." Titles and subsections of each appendix are as follows:

APPENDIX I: DESCRIPTION OF BASIN

- Section 1: Physical Description
- Section 2: Socio-Economic Base

APPENDIX II: WATER RESOURCES

- Section 1: Irrigation
- Section 2: Municipal and Industrial Water Supply
- Section 3: Rural Domestic and Livestock Water Supply
- Section 4: Development of Surface Water Resources
- Section 5: Surface Water Budgets (Including Pumped Groundwater)

APPENDIX III: EROSION AND SEDIMENT, AND FLOODING

- Section 1: Erosion and Sediment
- Section 2: Flooding

APPENDIX IV: RECREATION, FISH AND WILDLIFE, AND TIMBER

- Section 1: Recreation
- Section 2: Fish and Wildlife
- Section 3: Timber

LITTLE COLORADO RIVER BASIN
COOPERATIVE STUDY

ARIZONA - NEW MEXICO

APPENDIX III

EROSION AND SEDIMENT, AND FLOODING

This appendix was prepared pursuant to Section 6 of the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress, 68 Stat. 666, as amended and supplemented). This report is divided into two sections. Section 1 presents information on erosion and sediment problems and production rates. Causes of erosion and projected future conditions are discussed. Two alternative plans for resource improvement through the installation of conservation practices are presented. Some of the successes and failures of structures constructed in the past are documented; and recommendations are given for future construction of structural measures. Section 2 gives a brief review on the status of flood studies, describes existing and projected flood problems and discusses possible actions to reduce flood damages.

LITTLE COLORADO RIVER BASIN
COOPERATIVE STUDY

ERRATA SHEET

1. Effective July 1, 1981, Valencia County, New Mexico, was divided into two counties. That portion within the Little Colorado River Basin became Cibola County.

2. In June 1981, the Economics and Statistics Service was reorganized to form the Economic Research Service and the Statistical Reporting Service.

3. The Arizona Water Commission is now the Arizona Department of Water Resources.

LITTLE COLORADO RIVER BASIN

COOPERATIVE STUDY

APPENDIX III

EROSION AND SEDIMENT, AND FLOODING

CONTENTS

SECTION I

EROSION AND SEDIMENT

SECTION 1

EROSION AND SEDIMENT

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

PHOTOGRAPHS

PHOTOGRAPHS (Continued)

PHOTOGRAPHS (Continued)

MAPS

SECTION 1

EROSION AND SEDIMENT

INTRODUCTION

The Little Colorado River Basin encompasses an area of 17,256,960 acres in northeastern Arizona and northwestern New Mexico. The Arizona portion of the Basin includes 13,866,880 acres in Apache, Coconino and Navajo Counties. The New Mexico portion of the Basin includes 3,390,080 acres in Catron, McKinley, San Juan and Valencia Counties.

All lands in the Basin were evaluated to determine the rate of erosion within the Basin. In conjunction with this study, an evaluation was made to determine the quantities of soluble salts released by the erosion processes. Sediment transport and deposition were studied in order to determine where the sediment produced by the erosion was causing damages.

Rangelands were inventoried to determine vegetative cover conditions. This inventory was used as a basis to develop resource improvement needs by time frame and provided a basis for evaluating the effects of a land treatment program at various levels.

Economic evaluations of damages due to sediment deposition and salt loading are presented. Economic benefits expected to accrue as a result of installation of various levels of land treatment were determined.

Around 1880, widespread erosion and trenching of alluvial valleys occurred throughout the Southwest, including the Little Colorado River Basin. There is not common agreement as to the cause(s) of this erosion. As part of this study, USDA conducted an extensive literature review in an attempt to summarize the several theories on the causes of erosion. The result of USDA's study is presented in this report.

This report also presents data on the applicability of structural erosion control measures within the Basin. Although no structures are included in the alternative plans, the reader should not infer that structures are not needed in the Basin. A complete study of structural measures is beyond the scope and intent of this study. However, some of the successes and failures of structures constructed in the past and recommendations for future measures are presented.

PROBLEMS AND CONCERNS

EROSION

General

Erosion was identified as a major concern of residents throughout most of the Basin area. Erosion related problems include loss of land as a result of streambank and gully erosion, loss of soil nutrients, degradation of water

quality by sediment, sediment deposition in stream channels and reservoirs, damage to structural features on eroding land, and the release of soluble salts by the erosion process.

Erosion rates vary greatly within the Basin. Not only do these variations exist from place to place, but they vary greatly with time. Many interrelated factors are responsible for these variations. Some of these variations are directly related to climate. Such variables are especially apparent in an arid environment. Much of the precipitation which causes significant erosion occurs as infrequent, but intense, localized summer thunderstorms. One intense thunderstorm may cause more erosion than several years of so called average annual conditions. Climatic variations greatly influence the amount and vigor of vegetative cover which is very important in its effect upon erosion. Not only climatic variations affect vegetative cover. Man, through the utilization of vegetation for livestock grazing, exerts a great degree of influence upon vegetative cover. Destruction of vegetative cover, by whatever agent, may lead to an erosion cycle which may be extremely difficult to reverse if allowed to go unchecked. Wise use and management of the vegetation, on the other hand, permits its beneficial utilization for multiple objectives such as grazing, use by wildlife and erosion control.

There are other natural factors besides climate which influence erosion and over which man has relatively little control. Included are soil properties, steepness, length of slopes and shape of the land surface, the occurrence and geologic character of rock outcrops, and coarse fragments of rock and gravel on the land surface. Some soil properties which influence the erosion potential include: texture, structure, organic matter content and permeability. In some areas, an erosion pavement is present on the surface. This surficial layer of coarse sand or gravel frequently affords excellent protection of the soil from erosion so long as it is not disturbed. Such areas generally have low erosion rates even though little vegetative cover is present.

Present Conditions

By far the greater part of the Basin is rangeland used for grazing. Forested areas generally are also utilized to varying degrees for grazing. Sheet and rill erosion accounts for the larger amount of erosion in the Basin. Most of the sloping lands are experiencing some sheet and rill erosion. Areas with good grass cover and forested areas, generally found at the higher elevations, have relatively low rates of erosion (Photo 1-1). Many such areas have soils which are derived from volcanic materials. Higher erosion rates are most common in alluvial-filled valleys and on valley slopes where soils have developed on shales or material derived from shales (Photo 1-2). The highest erosion rates occur in areas of badland topography (Photo 1-3). This erosion is primarily geologic in nature. Typically, these badlands consist of poorly consolidated shales, mudstones and claystones and have little vegetative cover. Sheet, rill and gully erosion are active in these areas. Stream channel and gully erosion contribute significantly to total soil losses, particularly in the alluvial-filled valleys and on valley slopes of the Puerco, Zuni and Little Colorado Rivers (Photo 1-4). Sheet and rill erosion are generally active in those areas.

Photo 1-1: Rangeland with low erosion rate, Navajo County, Arizona. Good grass cover is responsible for low erosion rates.

Photo 1-2: Rangeland in Navajo County, Arizona undergoing severe sheet and rill erosion.

Photo 1-3: Severely eroding badland area in Apache County, Arizona. Note lack of vegetative cover.

Photo 1-4: Severe gullying of alluvial valley in Apache County, Arizona.

Locally, streambanks are undergoing severe erosion. In many areas, gully erosion is rapidly eroding areas adjacent to the river banks (Photo 1-5). Piping (the movement of soil particles by percolating water leading to the development of channels) is a problem on many of the soils. The collapse of soil overlying erosional pipes frequently leads to the development of large gullies (Photo 1-6).

Significant erosion of roadways occurs in parts of the Basin. There are many miles of unimproved dirt roads on the Indian reservations. These roads are often located with little regard for topographic or soil conditions. Many roads are abandoned, and new ones are made when they become impassable due to muddy conditions or when gullies form (Photo 1-7). There are also erosion problems associated with road cuts along improved roads. An example of such problems is seen on Highway 180 between Holbrook and St. Johns and intermittently throughout much of the Basin (Photo 1-8).

Generally, construction sites are areas with high erosion rates (Photo 1-9). These relatively small areas may undergo excessive erosion during construction operations. This excessive erosion rate is many times the average annual rate prior to the disturbance. While not considered a serious problem at this time, erosion on construction sites may intensify as parts of the Basin experience increased development. Careful planning of construction activities and installation of practices to control erosion and runoff from construction sites can greatly reduce this problem (Photo 1-10). Erosion may continue to occur at high rates if permanent erosion control measures are not included in the landscape design (Photos 1-11 and 1-12).

Photo 1-5: Severe streambank erosion, Puerco River, Apache County, Arizona.

Photo 1-6: Gully developed through piping erosional process in Zuni River Valley, Apache County, Arizona.

Photo 1-7: Eroding road on Navajo Indian Reservation, Apache County, Arizona.

Photo 1-8: Eroding road bank in Apache County, Arizona. Note sediment deposition in ditch.

Photo 1-9: Construction site at Show Low, Arizona, showing bare, disturbed soils subject to high erosion rates.

Photo 1-10: Sediment retention basin to store sediment from construction site shown in Photo 1-9.

Photo 1-11: Unprotected cut slope at ball field at Show Low, Arizona, showing high rate of erosion.

Photo 1-12: Sediment deposited on playing area of ball field from slope shown in Photo 1-11.

Five erosion classes are recognized in this report. Average annual erosion rates for each class, and the actual values used by USDA to compute the amount of erosion for this study are shown below.

Erosion Class	Average Annual Erosion Rate: Rate Per Class (acre feet/sq. mi./year	Average Annual Erosion Rate: Rate Per Class (tons/acre/year)	Average Annual Erosion Rate: Rate Used (acre feet/sq. mi./year)
1	>3.0	>9.0	4.0
2	1.0-3.0	3.0-9.0	2.0
3	0.5-1.0	1.5-3.0	0.75
4	0.2-0.5	0.6-1.5	0.35
5	<0.2	<0.6	0.15

The location and relative size of areas in each erosion class are shown on the Erosion Classification Map. Class 1 erosion occurs in scattered locations mainly in areas of badland topography. In the Arizona portion of the Basin these are too small to show on the map. Therefore, it is included within Class 2 delineations. Table 1-1 shows the area in each class and average annual erosion by Water Resource Council Hydrologic Units.

TABLE 1-1

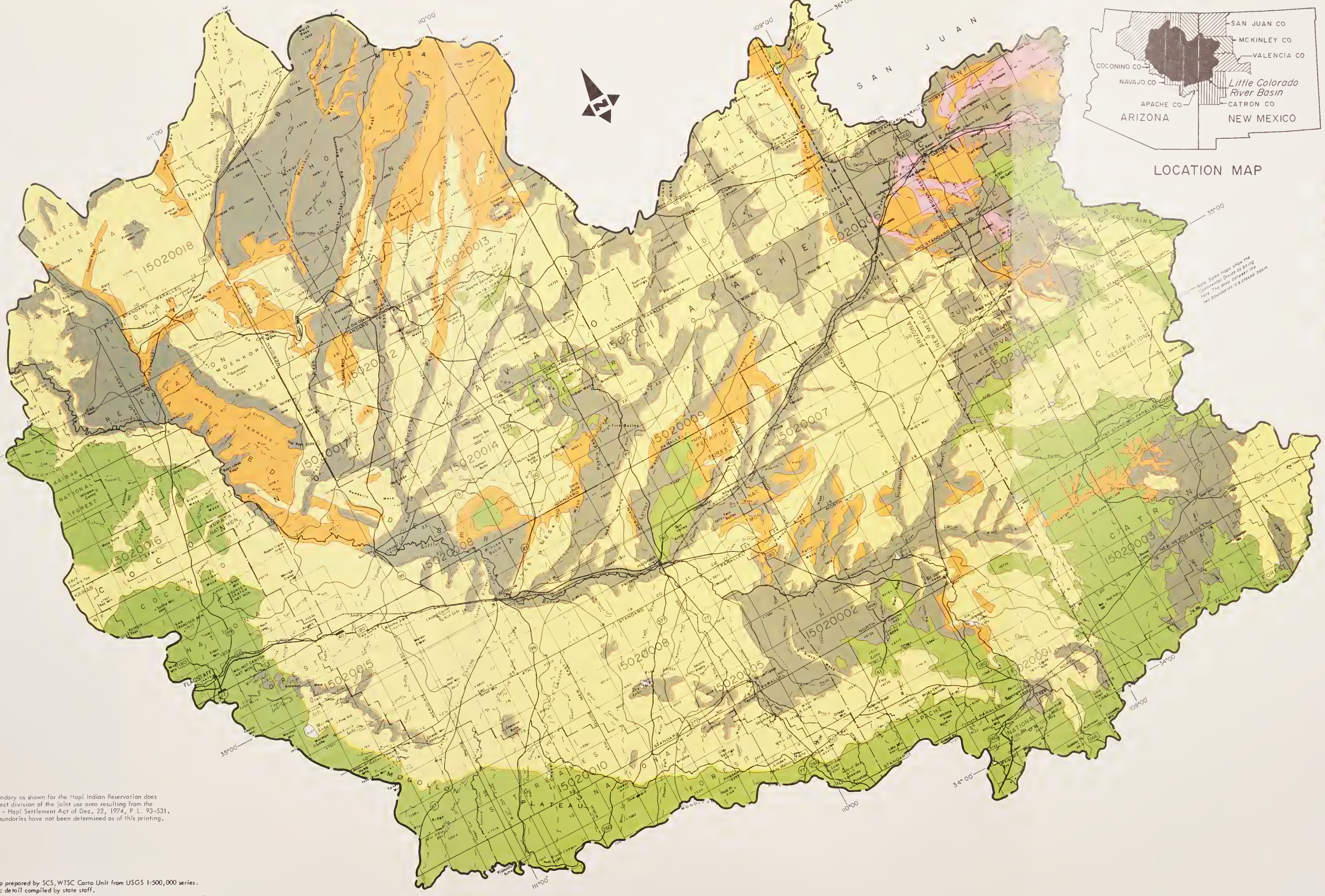
EROSION CLASSES AND AVERAGE ANNUAL EROSION

Little Colorado River Basin,

Arizona and New Mexico

Hydrologic Unit Code 1/	Erosion Class (Acres)					Average Annual Erosion 2/		
	1	2	3	4	5	Total Acres	1,000 TONS	TONS/ACRE
15020001	800	7,200	27,300	175,200	293,800	504,300	439	0.9
15020002	7,800	70,000	400,600	403,700	152,600	1,034,700	1,947	1.9
15020003		65,000	334,600	324,300	698,100	1,422,000	1,835	1.3
15020004	13,200	41,300	349,100	937,000	417,100	1,757,700	2,413	1.4
15020005			72,800	382,600	141,100	596,500	642	1.1
15020006	135,400	208,600	465,600	378,400	41,500	1,229,500	4,430	3.6
15020007	11,700	105,200	159,700	391,900	36,300	704,800	1,591	2.3
15020008	7,300	65,700	262,300	933,500	306,800	1,575,600	2,236	1.4
15020009	5,500	49,800	249,100	164,400	42,800	511,600	1,140	2.2
15020010				316,100	224,400	540,500	442	0.8
15020011	4,100	37,000	388,400	569,500	27,000	1,026,000	1,792	1.8
15020012	18,500	179,200	146,000	216,400		560,100	1,892	3.4
15020013	17,400	220,700	65,400	374,500	6,900	684,900	2,120	3.1
15020014	600	5,100	133,100	501,800	29,800	670,400	896	1.3
15020015			39,300	442,300	276,200	757,800	691	0.9
15020016	18,100	162,600	197,800	703,600	445,400	1,527,500	2,631	1.7
15020017	13,300	120,100	178,400	162,200		474,000	1,482	3.1
15020018	21,400	192,600	664,300	800,700		1,679,000	3,826	2.3
Totals	275,100	1,530,100	4,133,800	8,178,100	3,139,800	17,256,900	32,445	

1/ Water Resource Council Designation, (See Erosion Classification Map)
2/ See narrative preceeding this Table for the average annual erosion rate values that USDA used to compute tons of erosion.



LEGEND

PRESENT AVERAGE RATE OF EROSION *

- Greater than 3.0 Acre Feet Per Square Mile Per Year* (>9 Tons/Acre/Year)
- 1.0 - 3.0 Acre Feet Per Square Mile Per Year (3 - 9 Tons/Acre/Year)
- 0.5 - 1.0 Acre Feet Per Square Mile Per Year (1.5 - 3 Tons/Acre/Year)
- 0.2 - 0.5 Acre Feet Per Square Mile Per Year (0.6 - 1.5 Tons/Acre/Year)
- Less than 0.2 Acre Feet Per Square Mile Per Year (<0.6 Tons/Acre/Year)

* Areas of class 1 too small for mapping on this scale in Arizona. Other class delineations include areas of higher and/or lower rates too small for mapping.

Gully and streambank erosion not shown but is generally active within classes 1, 2 and 3.

15020004 Hydrologic Unit Code. U.S. Water Resources Council.

EROSION CLASSIFICATION

LITTLE COLORADO RIVER BASIN

ARIZONA AND NEW MEXICO

APRIL 1980

10 0 10 20 MILES

SCALE 1:1,000,000

Note:
The boundary as shown for the Hopi Indian Reservation does not reflect division of the joint use area resulting from the Navajo - Hopi Settlement Act of Dec. 22, 1974, P.L. 93-531. Final boundaries have not been determined as of this printing.

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.
Thematic detail compiled by state staff.

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA SCS PORTLAND OR 1981

M7-EN-23833-14

Present Conditions - Arizona: Severe erosion is occurring in the alluvial valleys and on the valley slopes of the Little Colorado, Puerco and Zuni Rivers and many of their major tributaries. Included among these are Moenkopi, Dinnebito, Oraibi, Wepo, Polacca, Jeddito, Streamboat, Pueblo Colorado and Coyote Washes. Less severe, but still serious erosion is occurring along Wide Ruin Wash, Black Creek, Hay Hollow Draw, and Millet Swale Wash. On the average, about 40% of the total soil losses in these areas is attributable to stream channel and gully erosion. Sheet and rill erosion is greater overall but the effects of the gully and stream channel erosion are the most damaging.

Gully erosion and associated piping erosion is locally very severe in the alluvial valleys near the channel banks. This is especially true in the middle and upper reaches of many of the main washes and their tributaries. Many gullies are rapidly extending themselves by headcutting (Photos 1-13 and 1-14). Gully erosion is locally very active on valley slopes.

About 5,300 miles of channel banks are experiencing moderate to severe erosion. Erosion rates in these banks range from about 250 to 6,500 tons per bank mile on an average annual basis.

Areas with relatively low erosion rates include much of the area south and west of the Little Colorado River and the interstream divides in other parts of the Basin. Also included in this category are the headwaters of the Little Colorado River and part of the Defiance Plateau. In areas of deep, sandy soils with low rainfall, water erosion rates are generally low even though vegetative cover may be sparse. High infiltration rates reduce runoff and reduce erosion from water. However, wind erosion may be locally severe under such conditions.

Photo 1-13: Headcutting gully destroying good rangeland in Apache County, Arizona.

Photo 1-14: Headcutting gully in small valley, Navajo County, Arizona.

Present Conditions - New Mexico: High erosion is occurring in the alluvial valleys of the Puerco and Zuni Rivers and their tributaries. Tributaries of the Puerco River with moderate to severe erosion are Bread Springs Wash, Burned Death Wash, Defiance Draw and Manuelito Canyon. The Rio Nutria and Rio Pescado are tributaries of the Zuni River with moderate to severe eroding streambanks and gullies. Lesser erosion is occurring on Tohdildonih Wash, Salt Water Wash, Squirrel Springs Wash, South Fork of the Puerco and Bowl Canyon Creek. Within New Mexico there are about 250 miles of moderate to severe streambank and gully erosion.

Areas of high streambank erosion generally have higher sheet, rill and gully erosion. Areas where sheet and rill erosion are high are in the drainages of Bread Springs Wash, Burned Death Wash, Defiance Draw, Salt Water Wash, Tohdildonih Wash, Bowl Canyon Creek and Coal Mine Wash. These areas have been and are being heavily grazed. The highest sheet, gully and streambank erosion is occurring in areas west of State Highways 32 and 666 from the Jones Rank School area north to the Red Lake area north of Window Rock.

Physical Effects of Erosion

Sheet and rill erosion results in the removal of thin layers of soil. Along with the removal of the soil particles, plant nutrients and organic matter are also removed. This process reduces the productive capacity of soil with already low natural fertility. In areas of shallow soils, the remaining soil profile may become so thin that root development of plants is seriously impeded, resulting in reduced plant vigor. Due to the slow rate of soil development in an arid environment, even low rates of erosion may be serious.

Loss of land is a major consequence of streambank erosion. The generally low value of rangelands in the Basin lessens the overall economic impact from this type of erosion. In some areas, as near Tuba City and St. Johns, higher value lands are being lost to streambank erosion.

Channel entrenchment occurs as a result of downcutting of the channel bottom by erosion. Entrenchment of drainages as much as 30 to 60 feet in some areas has lowered the water table of adjacent land. This process has deprived some of the vegetation of its former supply of water. Reduced plant vigor and changes in vegetative types have occurred in some areas. This lowering of the water table has seriously damaged many formerly productive areas, particularly on the Indian reservations.

The effects of gully erosion are perhaps the most noticeable of the various types of erosion in the Basin. Utilization of the land is made more difficult where gullies impede the movement of livestock and equipment. Gullies concentrate the flow of runoff water. They quickly convey it to the main channels. This rapid removal of water from the land surface greatly reduces the infiltration of water into the soil profile. Thus, large amounts of water are lost from beneficial use by plants growing in the area. As a result, vegetative cover is greatly reduced, both in vigor and quantity. The impact is very serious in many areas. Gullies may intercept and lower the water table thereby drying up meadows and wetlands.

Erosion releases soluble salts from soils and geologic materials. The amount of salt released is determined by the salt content of eroding materials, rate of erosion, and kind of erosion processes at work. Soluble salt content of the eroding materials varies greatly. Geologic formations with relatively high salt content include the Chinle of Triassic age and the Mancos Shale of Cretaceous age.

The Moenkepi Formation (Triassic age) may locally have relatively high salt content. Soils with locally high salt content are saline and/or alkali phases of the Lohmiller, Moriarty, Navajo, Tours, Jocity and Ives series. (Further information on the soils in the Basin is presented in Appendix I, Section 1). Saline and alkali affected soils generally follow the outcrop pattern of the Mancos Shale. These areas generally have high rates of erosion. Soils and geologic materials with relatively high salt content are found mainly north and east of the Little Colorado River and in the valleys of the Little Colorado, Zuni and Puerco Rivers.

Salt content, as determined by sampling, is highest in the subsurface. Because of this, streambank and gully erosion releases more salt per unit volume of sediment than does sheet and rill erosion.

About 87,600 tons of salt, on an average annual basis, are released in the Arizona portion of the Basin through erosion. Of this total, it is estimated that about 59,600 tons, (68 percent), come from badland areas where geologic erosion is very active. About 14,700 tons of salt are trapped in closed basins leaving about 72,900 tons of salt available for transport from the Arizona portion of the Basin of which about 65,600 tons are transported to the Colorado River. The New Mexico portion contributes

about 6,300 tons of salt annually, for a Basin total of about 71,900 tons of salt per year to the Colorado River. By comparison, about 550,000 tons of salt enters the river annually via spring flow (USDI, 1977).

Water quality is degraded by salts which enter the streams as a result of erosion and resultant salt release. This salt adds to the salinity problems of the Colorado River.

SEDIMENT

General

Sediment is the by-product of erosion. It is defined as solid material that has been detached from its place of origin and is being transported or has been deposited. Sediment transport occurs at variable rates in response to runoff. It is dependent upon erosion to produce the sediment. Sediment transport in the Basin is greatest in response to intense summer thunderstorms which produce rapid runoff. Because of the infrequent occurrence and short duration of large flow events, the average annual sediment yield for much of the Basin is relatively low.

Just as there are many variables influencing erosion, there are also many variables affecting sediment delivery or sediment yield. Sediment may be dropped near its point of origin, or it may be transported for very long distances. Some of the natural factors which influence sediment delivery include: (1) the type of erosion forces at work, (2) particle size of sediment, (3) velocity of water or wind transporting the sediment, (4) distance from sediment source to a defined channel, (5) climatic factors, and (6) topography. In addition to these natural factors, man's activities influence sediment transport in many ways. The construction of dams greatly alters the sediment transport processes. Many reservoirs within the Little Colorado River Basin trap sediment which would otherwise ultimately be transported to the Colorado River. Structures such as water spreaders, dikes and diversions also alter the sediment delivery processes. Irrigation diversions divert sediment along with water from streams. The capacity of a stream to transport sediment is reduced as a result of the diversion of water for various uses.

Physical Effects of Sediment

Sediment has long been recognized as the greatest single pollutant of our surface waters. The effects of sediment production within the Basin are far reaching, extending far beyond the Basin boundaries. About 10.2 million tons of sediment (see Table 1-2) are transported to the Colorado River by the Little Colorado River on an average annual basis. Most of this sediment will ultimately reach Lake Mead. The greater portion of it will be deposited there. However, some of it will be transported even greater distances downstream. Water quality is degraded by this sediment.

Sediment remaining in the Basin is deposited in numerous places and is generally damaging in its effects. Perhaps the most readily apparent areas of deposition are in the reservoirs (Photo 1-15) and channels. Sediment deposits in reservoirs have reduced their capacity to store water for beneficial purposes. Lyman Lake, Zion Reservoir, Ojo Caliente, Black Rock, and the Nutria Reservoirs have lost significant amounts of storage to sediment. Many small reservoirs have been completely filled with sediment. In many areas the rate of sediment accumulation is so high that construction of reservoirs is not feasible, particularly on much of the Navajo and Hopi Reservations. About 3.3 million tons of sediment per year are deposited in impoundments in the Arizona portion of the Basin.

Sediment carried in suspension degrades water quality. Damaging effects may occur when sediment-laden water is used for irrigation. Sediment deposited on irrigated lands can change the texture of the soil surface and restrict intake rates. Sediment also necessitates more frequent land leveling and maintenance. Sediment deposited in irrigation canals increases operating costs for sediment removal. Fish and wildlife values are often adversely impacted by sediment which is carried in suspension or which is deposited in reservoirs and streams.

Photo 1-15: Reservoir storage capacity has been severely reduced due to sediment filling of this Navajo County, Arizona reservoir.

In some cases sediment carried by irrigation waters is beneficial to coarse textured soil. Also, sediment can help reduce seepage from earth canals constructed in coarse textured materials and removal of the sediment can increase seepage losses.

Sediment deposition is occurring in many streams and channels in the Basin. This may have either adverse or beneficial effects. Adverse effects are occurring in the Little Colorado River near Holbrook, Joseph City (Photo 1-16), St. Johns and Winslow, where sediment deposits have reduced the capacity of the river to convey flood flows. Floodwaters overflow the streambanks and the incidence of flooding is increased. Vegetative growth on sediment deposits further restricts channel capacity and induces even more flooding and sediment deposition. In New Mexico, the Zuni River channel at Zuni Pueblo has aggraded, causing a flooding problem.

Sediment deposition increases the cost of highway maintenance. Sediment deposits can reduce the capacity of bridges and culverts to convey floodwaters (Photo 1-17). The removal of sediment from culverts and road ditches presents a continual maintenance problem at many locations.

Beneficial effects of sediment deposition may occur when sediment is deposited in incised channels. The sediment reduces streambank erosion and induces vegetative growth. Examples include Dead River and Leroux Wash where deposition is naturally occurring as a result of aggradation. Also on Polacca and Wepo Washes due to the construction of structures which have caused sediment deposition in deeply incised arroyos for a distance of several miles upstream (Photo 1-18).

Photo 1-16: Channel of Little Colorado River nearly completely filled with sediment near Joseph City, Arizona.

Photo 1-17: Culvert through highway near Window Rock, Arizona completely filled by sediment.

Photo 1-18: Sediment deposited about 6 miles upstream of Polacca Dam No. 2. Prior to deposition, channel was about 30 to 40 feet deep.

Within the Basin there are a number of drainages, covering about 5,000 square miles, that end in basins with either no natural outlet or severely restricted outlets. About five million tons of sediment per year are deposited within these basins. Only a small amount of sediment leaves those basins which are infrequently drained. No sediment leaves those with no drainage outlet. Sediment yield from the total Basin is substantially reduced because of the deposition which occurs in these areas. (See Areas Which Contribute Little or No Stream Flow to Little Colorado River Map.)

Average annual sediment yields are shown in Table 1-2 and on the Sediment Yield Map.

TABLE 1-2

SEDIMENT YIELD 1/
LITTLE COLORADO RIVER BASIN,
ARIZONA AND NEW MEXICO

WRC Hydrologic Unit 2/	Sediment Yield (Thousands of Tons)
15020001	135
15020002	627
15020003	328
15020004	505
15020005	194
15020006	923
15020007	534
15020008	570
15020009	607
15020010	144
15020011	946
15020012	134
15020013	997
15020014	388
15020015	197
15020016	764
15020017	814
15020018	1,412
TOTAL	10,219

1/ These values represent average annual sediment yield to the Little Colorado River main stem.

2/ Hydrologic units as designated by U.S. Water Resources Council.

LOCATION MAP

LEGEND

15020006 Hydrologic Unit Code U.S. Water Resource Council

923 (470) Average Annual Sediment Yield to Main Stem of the Little Colorado River from Individual Subbasin. (Upper Figure Represents Thousands of Tons; Lower Figure Represents Acre Feet.)

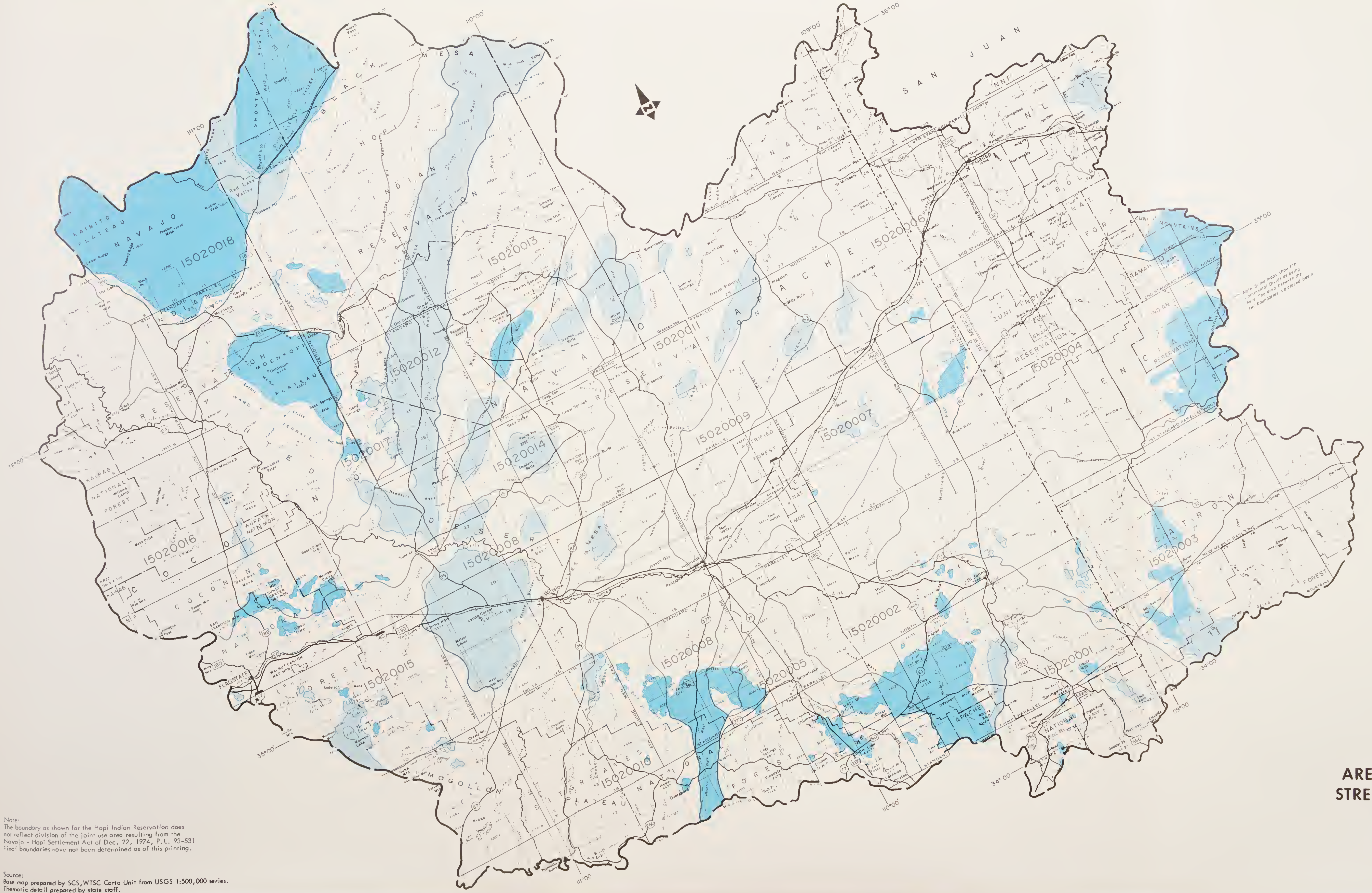
SEDIMENT YIELD
LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

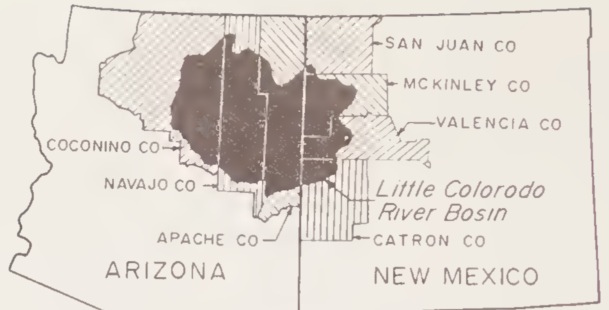
JULY 1980

10 0 10 20 MILES
SCALE 1:1,000,000

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.
Thematic detail compiled by state staff.
U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA SCS PORTLAND OR 1981

M7-EN-23833-18





LOCATION MAP

LEGEND

Areas Of External Drainage Only During High Stream Flow

Areas Of No External Drainage

BY
ARIZONA WATER COMMISSION
NEW MEXICO STATE ENGINEER
AND
U.S. DEPARTMENT OF AGRICULTURE

AREAS WHICH CONTRIBUTE LITTLE OR NO STREAM FLOW TO LITTLE COLORADO RIVER

LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

SEPTEMBER 1979

10 0 10 20 MILES
SCALE 1:1,000,000

Note:
The boundary as shown for the Hopi Indian Reservation does not reflect division of the joint use area resulting from the Navajo - Hopi Settlement Act of Dec. 22, 1974, P.L. 93-531 Final boundaries have not been determined as of this printing.

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.
Thematic detail prepared by state staff.

U.S DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA SCS PORTLAND OR 1979

M7-EN-23833-6

Economic Damages from Sediment

Average annual erosion rates vary from less than 0.6 tons per acre in Erosion Class 5 to over 9 tons per acre in Erosion Class 1. The class, and thus the erosion rate, varies from one part of the Basin to the other. (See Erosion Classification Map.) The total erosion has been estimated at 32.4 million tons per year (see Table 1-1).

The end product of erosion is sediment. It is estimated that about 10.2 million tons (see Table 1-2) or 32 percent of the total sediment produced within the Basin is transported by the Little Colorado River to the Colorado River. Assuming that most of this volume is delivered to Lake Mead, and with a sediment to storage ratio of one acre-foot per 2,100 tons of sediment, then about 5,000 acre-feet of storage could be lost annually. This would amount to about 500,000 acre-feet in 100 years, about 1.9 percent of the usable capacity of Lake Mead in 1967 (USDI, 1978).

Other factors to be considered in evaluating the effect of sediment accumulations in Lake Mead include water quality, power values and salinity. None of these were evaluated except the reduction in salinity of Colorado River water.

Under present conditions, the erosion process and the associated salinity of the sediment from the Little Colorado River Basin adds about 72,000 tons of salt annually to the Colorado River. If this is related to the salinity of the Colorado River Water at Imperial Dam with a value of \$52 1/ per ton of salt, the damages are estimated to be about \$3.7 million annually. However, the major contributor of salt from the Basin is Blue Spring and other springs located near the Basin's mouth. About 550,000 tons of salt are estimated to be entering the Colorado River from these sources which causes about \$28.6 million of damages annually when estimated at \$52 per ton. Methods of controlling the salinity from these springs were not investigated.

The deposition of sediment in the Little Colorado River, especially in or near St. Johns, Holbrook, Joseph City and Winslow, has led to increased flooding in these areas. Damages due to the increased flooding were not investigated for this study, but have been investigated by the Army Corps of Engineers at Holbrook and are being investigated by the Arizona Department of Water Resources at Winslow.

Other sediment problems include loss of storage capacity in reservoirs. The annual sediment accumulations are about 1,400 acre-feet in stockwater tanks and about 700 acre-feet in other reservoirs used for irrigation, recreation, and fish and wildlife. These losses, totaling about 3.4

1/ Source: "Salinity Management Options for the Colorado River-Damage Estimates and Control Program Impacts," June 1979. Prepared by consortium of Water Resources Centers in the states of Arizona, California, Colorado and Utah. Updated July 1980 to \$52 per ton.

million cubic yards, are valued at $6.8 million per year; based on two dollars per cubic yard for sediment removal. Another method for evaluating the storage loss would be to determine the replacement cost for the storage facilities. These costs were not computed.

The annual cost of sediment removal from bridges, culverts and road ditches within the Basin is estimated at $0.3 million per year. This estimate is based on data from the Arizona Department of Transportation and the Coconino County Highway Department. It is estimated that about 41,350 cubic yards are removed each year at a rate of about $7 per cubic yard.

CAUSES OF EROSION

This section discussed the possible causes of loss of grass cover and erosion in the Little Colorado River Basin and elsewhere in the arid and semiarid Southwest. Included is a discussion of six theories explaining the cause of the widespread erosion and trenching of alluvial valleys that occurred throughout the Southwest at the turn of the 19th century.

A determination of the causes of erosion in the Basin is important. A better understanding of the erosion causing factors would aid in developing erosion control practices to alleviate the problem. Unfortunately, there is not common agreement as to the cause(s) of erosion. However, much can be accomplished by recognizing the existence of the problem and applying currently available technology to the treatment of existing problems.

HISTORICAL PERSPECTIVE

Thornthwaite, Sharpe and Dosch (1942) report that Lieutenant Edward T. Beale, in the fall of 1857, gave a glowing account of grass cover on the upland areas between Holbrook and the mouth of Canyon Diablo on the Little Colorado River. He stated that "nothing impeded their progress but grass." Upon his return trip east, he described the vegetation on Second Mesa as being sparse. He described Wepo Valley as being well covered with grass. Other travelers in the area, including Colonel Kit Carson (1863) and Captain John Bourke (1881), make frequent mention of both mesas and valleys where grama grass grew luxuriantly, but with interspersed areas where vegetation was sparse. Bourke, in August 1881, described what is presently known as Wepo Wash as a rainy season stream 20 feet wide and 3 to 6 inches deep with a swift current. He also mentions crossing an alkali flat full of mud holes and two ravines about 10 feet deep. These two ravines are believed to be Wepo and Polacca Wash. It is believed that these present-day massive arroyos were discontinuous channels at that time.

The conditions as described above by Beale, Carson and Bourke changed drastically in the late 1800's as a period of severe erosion began in the Little Colorado River Basin and elsewhere in the arid and semiarid Southwest. Normal washes were changed to massive trenches (see Photos 1-19 and 1-20) consisting of deep gullies cut through valley alluvium in barren valley floors. This was accompanied by desiccation and deterioration of millions of acres of land. This process has been commonly referred to as "accelerated erosion" by some authorities (Thornthwaite, et al. 1942).

Photo 1-19: Puerco River, Apache County, Arizona. Aerial view of trenched valley.

Photo 1-20: Polacca Wash, Navajo County, Arizona. Ground view of trenched valley.

USDA uses the term "valley trenching and related erosion" in this report (after King, 1970) because accelerated erosion, by definition, is generally attributed to the activities of man and there is no hard proof that man is solely responsible.

Thornthwaite et al., states, "The weight of evidence indicates that accelerated erosion began between 1880 and 1885 and gradually spread until about 1914 when all the major drainages and most of the larger tributaries were trenched by a system of continuous gullies." Hoover (1930) as reported by Thornthwaite et al., stated of Oraibi Wash, "The old Oraibi Wash of 30 years ago was no more than five or six feet deep and can still be traced where it was abandoned for the great gash about 35 feet deep and several hundred feet across. Locally, it has cut to bedrock and here there is a constant flow of surface water. It is representative of what has taken place in all the valleys."

There is a considerable diversity of opinion, even among scientists, as to the cause of valley trenching and related erosion within the Basin and elsewhere in arid and semiarid lands. Perhaps the most popular theory, at least with the general public, is that erosion is due to overgrazing and land abuse. This theory is not universally accepted; in fact, some investigators reject it categorically.

GEOLOGIC, NORMAL AND ACCELERATED EROSION

The Soil Conservation Society of America (1970) defines geologic, or natural erosion as "Wearing away of the earth's surface by natural agents under natural environmental conditions of climate, vegetation, etc. and undisturbed by Man."

Normal erosion is defined as "The gradual erosion of land used by man which does not greatly exceed natural erosion."

Accelerated erosion is defined as "Erosion much more rapid than normal erosion, natural erosion or geologic erosion, and occurring primarily as a result of the influence of the activities of man or, in some cases, of other animals or natural catastrophes that expose bare surfaces (for example, fires)."

Other authorities attribute accelerated erosion solely to man's activities. For instance, the U.S. Forest Service (1976) defines accelerated erosion as "Erosion that can be attributed directly or indirectly to the activities of man." Howell (1957) defines it as "Erosion at a rate greater than normal for the site, brought about by man, usually through reduction of the vegetal cover."

The rate of erosion or amount of sediment production are not critical in determining if an area is in a state of geologic or accelerated erosion. Rates of geologic erosion are extremely variable from one locality to another.

There is a lot of disagreement about whether a given area should be classified as geologic or accelerated erosion. Some individuals argue that man's activities, particularly in the western United States, have had some detrimental effect on all lands, thus, all lands are under a state of accelerated erosion.

From a technical standpoint, it does not matter whether an area is classified as being of geologic or accelerated erosion. Either it is feasible to treat the land or it is not. The term "geologic" erosion does not mean "untreatable" erosion any more than the term "accelerated" erosion means that an area can or should be treated.

THEORIES ON THE CAUSES OF VALLEY TRENCHING AND RELATED EROSION

For this study, USDA reviewed a wealth of published information by highly qualified researchers on the cause of the cycle of erosion that began in the late 1800's in the Southwest. The various theories have been well summarized by such writers as Thornthwaite, et al. (1942), King (1970), Hastings and Turner (1965) and Hastings (1959). Although some of the literature reviewed describes areas outside of the Little Colorado River Basin, the causes of valley trenching and erosion that occurred within the Basin are the same as the causes throughout the arid and semiarid Southwest.

There are six theories on the cause of valley trenching and related erosion: (1) overgrazing and land abuse, (2) climatic changes, (3) infrequent intense storms, (4) diastrophism or tectonic activity, (5) rodents and jackrabbits, and (6) fire suppression. The first three theories are the major ones and have received the most attention and investigation. Some authorities assume rigid positions in favor of a single theory while others recognize multiple causes.

Overgrazing and Land Abuse

Proponents of this theory argue that the indiscriminate use of land and overgrazing caused depletion of grass cover, soil compaction by livestock, and roads and trails that concentrate runoff and cause erosion. There is a strong argument for this theory because the dates of increased erosion coincide with settlement. Hastings and Turner (1965) report that Cottam and Stewart (1940) showed channeling of Mountain Meadow, Utah (1884) followed settlement (1862). Further, Bailey (1935) shows a similar relationship between settlement (1868) and channeling (1883) on Kanab Creek. Colton (1937) states that settlement (1878) and overgrazing (the 1880's) initiated floods (early 1890's) on the Little Colorado River. Other proponents of the overgrazing theory include Bennett (1939) and Antevs (1952).

There is strong evidence to support the overgrazing theory. Hastings (1958) reports that in 1883, before trenching of the San Pedro River in Cochise County, Arizona, there were only 68,000 cattle in Pima, Cochise and Graham counties. The number had increased to 156,000 in 1886 and 253,000 in 1890, when channeling began on the San Pedro and Santa Cruz Rivers. Hastings compared three parameters in his analysis; cattle

population, summer rainfall and the incidence of flooding and cutting. In 1882, with a summer rainfall of 7.08 inches and 50,000 head of cattle there were no unusual flood conditions. In 1886, with only 4.63 inches of rainfall and 156,000 cattle some flooding did occur, and in 1890, with 7.92 inches and 253,000 head of cattle there was tremendous flooding and erosion damage. These statistics would appear to strongly support the overgrazing theory.

The San Simon Valley in Graham County, Arizona is one of the most severely eroded areas in Arizona. It is entrenched up to 20 feet in depth for over 60 miles. This valley was not severely eroded before the coming of Anglo settlers. Knechtel (1938) reports that Mormon settlers who arrived from Utah around 1880 found luxuriant growth of grass and the present gully of San Simon Wash did not exist. The Graham County Board of Supervisors (1935) report that Samual W. Cozzens (1859) showed the valley to be covered with grama grass and to contain fine grazing land. They also report on the work of Olmstead (1903) who states that the trenching of San Simon Wash began in 1899 becuase farmers dug a ditch about four feet deep and 20 feet wide to protect their fields from floodwaters. Olmstead states "it worked, and today (1919) there is a chasm, in many places 600 to 800 feet wide and from 10 to 30 feet deep for 60 miles."

Knechtel, also quoting Olmstead, relates that the ditch was dug in 1883 instead of 1899. Olmstead stated that a major cause of the trenching was a wagon road between Solomonville and Bowie. Weiler (1969) lays the blame on severe overgrazing by 50,000 head of cattle in the early 1890's followed by drought during the years of 1902 to 1905. Heavy rains in 1905 and 1906 started the trenching. Bryan (1925) feels that the trenching was due to climatic change instead of overgrazing. Gregory (1934) as related by Knechtel (1938) feels that the trenching was due to recent regional tectonic activity.

Regardless of the actual role that overgrazing had on the erosion that occurred in the late 1800's, the fact remains that livestock do deplete grass cover, trampling reduces grass cover and increases the potential for runoff and erosion by compacting the soil, and stock trails concentrate runoff and cause increased erosion. Much of the research that has been done on the impacts of livestock are well summarized by Hastings and Turner (1965), the U.S. Bureau of Land Management (1978), Gifford and Hawkins (1976) and others. Control of domestic animals is essential to the success of any land treatment program. Proper range use should be the first increment of a land treatment program.

Climatic Changes

Proponents of the climatic theory argue that climatic changes are more responsible for the decrease in grass cover and erosion than cattle.

A variety of theories have been suggested; there is less rainfall than previously; there have been shifts in rainfall patterns; there has been a change in the time of the beginning of the summer rainy season; and there has been a change in the number of small rains.

There are various degrees to which this theory is supported. At one extreme are those writers who believe that climate is solely responsible for increased erosion. Others subscribe to the "trigger-pull" theory, which states that the long-term climatic changes had already begun in the Southwest by 1880, and that conditions were approaching the critical point where erosion would probably begin anyway. The introduction of large herds of cattle merely served as the trigger pull to set off a loaded weapon (Hastings, 1958).

Campbell (1969) studied sheep stocking on the Shonto Plateau of the Navajo Reservation and he observed that although stocking increased from 28,000 sheep units a year in 1936 to over 35,000 units in 1968, there was no increase in gullying. He concluded that climatic variation and not overgrazing is the cause of increased erosion. This position was echoed by Gregory (1950) commenting on erosion on the Navajo Reservation that "parts of the region not utilized for grazing present the same detailed topographic features as the areas annually overrun by Indian herds."

Also, Peterson (1950), observed that there was trenching on the Fort Bayard Military Reservation where grazing had been either excluded or rigidly controlled.

The German geologist, Baron Von Richthofen, and Ellsworth Huntington feel that the decadence of North China was due to desiccation or pulsations of the climate (Lowdermilk, 1960). In contrast, Lowdermilk places the blame in this same area on overgrazing and land abuse.

Bryan (1925) points to geologic evidence of past cycles of erosion and aggradation. He feels there have been four, including the one we are presently under. He concludes that if trenching has occurred before, then clearly something other than cattle must be the cause. Leopold and Snyder (1951) studied climatic records between 1850 and 1870 to show a reduction in the number of small rains but no change in the amount of annual precipitation. They believe that climatic variation started the current cycle of arroyo cutting but overgrazing and land abuse was the "trigger" to initiate arroyo cutting.

Schulman (1947) and Stockton and Jacoby (1976) analyzed climatic and tree-ring data and conclude that the climate has not changed. The magnitude and frequency of storms in the Southwest have followed the same pattern for centuries.

Judson (1952) associates arroyo cutting with periods of deficient rainfall and feels that it is extremely doubtful that even the strictest control of grazing, combined with "upstream engineering", will bring alleviation unless it is accompanied by sufficiently effective precipitation.

Infrequent Intense Storms

Thornthwaite, Sharpe and Dosch (1942) place little credibility in the climatic change theory. They conducted an intensive study of climatic records on the Navajo Reservation and feel that the process of erosion and aggradation results from the irregular occurrence of heavy storms rather than any change in climate. However, they do not discount the effect of overgrazing--considering it the "gun" that touched off the epidemic of erosion. This view is shared by Dellenbaugh (1922). Gregory (1950) reports that large floods on Kanab Creek in 1883 cut a channel 60 feet deep, 60 to 70 feet wide, and seven miles long. Wooley (1946) reports that a flood in 1883 moved masses of earth as large as a house down Kanab Creek.

Regardless of the exact impact of large storms in the 1880's, it is a proven fact that they can cause massive erosion along stream channels in alluvial valleys. The Gila River near Safford in Graham County, Arizona sustained major widening during the large flood that occurred in the spring of 1980. Similar examples can be cited. Upstream land treatment is ineffective against this type of storm. Large storms can only be controlled through large retention or detention dams, channels, or grade control structures.

Rodents and Jackrabbits

There is a theory put forth by some writers that rodents and jackrabbits are responsible for the loss of grass cover, thus setting the stage for increased erosion. Man has contributed to this problem by controlling snakes, coyotes and other predators.

The subject is reviewed quite well by Hastings and Turner (1965) who tend to place little credibility in this theory as a major factor in the loss of cover on the desert grasslands of southern Arizona. These writers conclude that rodents and jackrabbits reach great numbers only on depleted ranges. Nevertheless, there are instances where they should be controlled. Burrowing rodents can cause the failure of earth embankments. Rabbits can destroy emerging vegetation.

Diastrophism

There is a theory that valley trenching is a result of earth movements, including earthquakes, uplifts and earthcracks. Some people attribute the trenching of the San Pedro to an earthquake in 1890.

There is little in the literature to support this theory. Knechtel (1938) reports that Gregory (oral communication, 1934) was "inclined to regard recent regional tectonic activity as a possible cause of the trenching of the San Simon Valley, an explanation which Bryan rejected."

Fire Suppression

The proponents of this theory argue that man's suppression of range wildfires has allowed the invasion of woody plant species to the detriment of grass cover.

This theory has been hotly argued in recent years. Hastings and Turner (1965) conclude that fire suppression is probably not a major force leading to widespread erosion. There was certainly little control of wildfires during the 1880's. Nevertheless, destructive wildfires should be controlled. Fire can cause serious erosion problems, especially if hard rains fall on steep, barren slopes, or if the soil is easily eroded.

Summary

There are three theories on the cause of valley trenching and related erosion that appear to have validity; overgrazing and land abuse, climatic changes, and large infrequent storms.

The proponents of the overgrazing and land abuse theory believe that the most effective method of treatment is grazing control and plant restoration by various treatment practices. Their focal point is upstream; keep the rain where it falls. Large expensive structures are not needed.

In contrast, the proponents of the large intensive storm theory generally place little value on the effectiveness of small structures or other land treatment practices and advocate the use of large water retention, detention or grade control structures. Leopold and Miller (1954) assume a medium position, stating that "land use may reinforce or counteract the effect of climate...this does not require an abandonment of measures for improvement of land use." This thought is echoed by Thornthwaite, Sharp and Dosch (1942).

Hastings and Turner (1965) writing about southern Arizona conclude that "the conviction grows that we are not merely at one stage of a cycle repeating itself, but that the past 80 years have witnessed the evolution of a significant new vegetation (woody instead of grass). This new vegetation is in response to the unique combination of climate and cattle." They also state that "there is no evidence that the elimination of grazing can bring about their (woody plants) disappearance, once they have become established."

King (1970) subscribes to all three major theories. The causes are multiple and reflect complex interrelationships among many factors. He believes that presettlement periods of erosion were initiated by climatic shifts. The present period of erosion was brought on largely by land abuse. Large floods from intense storms have always caused localized valley trenching.

King supports his theory that the present erosion is primarily due to land abuse by citing the parallel development of erosion in Israel (Lowdermilk, 1960) and in South Africa. He reports on a personal conversation with D.W. Immelman (Chief Professional Officer, Division of Agricultural Mechanization and Engineering, Regional Office, Queenstown, S.A.) that the valleys in South Africa were stable or aggrading until being subjected to intense grazing pressures following white settlement, at which time they began to trench.

In summary, all three of the major theories; overgrazing and land abuse, climatic changes and high intensity storms, are probable causes of erosion. Anyone familiar with areas that have been severely overgrazed cannot ignore

the evidence that this can be a major factor in erosion. At the same time, one can cite examples of areas protected from grazing, like highway right-of-ways, where vegetal cover is sparse and erosion continues. Climate must be a factor. Likewise, there is much documentary evidence that a large flood from an intense storm can cause severe valley trenching.

OTHER CAUSES OF EROSION

Insects and Wildlife

King (1970) summarizes much of the research that has been done on the impacts of insects and wildlife on vegetal cover. There are isolated instances where large mammals, grasshoppers, harvester ants and termites have caused local damage, however, the instances are infrequent.

Grasshopper infestations in the Little Colorado River Basin have occurred in several instances, the most recent being in the fall of 1979 and 1980.

Indiscriminate Land Use

The damages caused by offroad vehicles, improper road location, pipeline and transportation corridors, mineral and energy exploration and extraction, and other human land use factors are obvious to the most casual observer. Fortunately, the tools are available to control much of the erosion induced by human abuse and the incidences are less frequent than in past years.

FUTURE CONDITION WITHOUT PLANNED ACTION

The future erosion and sediment conditions in the Basin without planned action must be projected to provide a basis for identification of needs, development of alternative plans, and measuring plan impacts.

The future without plan, or projected condition, is defined as the condition expected to exist in the future as a result of development and changes over time without new projects or programs, other than those authorized and funded, and without acceleration of ongoing programs. The projection years are 1990, 2000 and 2020.

USDA is of the opinion that the future without plan erosion conditions and sediment delivered to the mouth of the Basin will not be significantly different than existing conditions. There may be changes in erosion rates at different areas within the total Basin but degradation in some areas will be offset by improvement in other areas. The rational for this conclusion is presented in the following sections.

ASSUMPTIONS

Projections of land use, development and other factors that will impact upon erosion rates and sediment yield within the Basin are based upon the following assumptions:

1. Historic trends provide insight for the future.

2. Technological advancements will continue.

3. Land resources are limited in quantity.

4. Labor availability will be adequate.

5. Capital will not limit the level of ongoing land treatment programs.

6. There will not be major changes in existing surface water rights or use of surface water

PROJECTED PROJECTS

Major water resource development projects currently under study in the Basin are discussed in Appendix II, Section 4, DEVELOPMENT OF SURFACE WATER RESOURCES. These projects include: (1) USDA's Public Law 566 Cottonwood Wash Project, Navajo County, Arizona, (2) the U.S. Bureau of Reclamation (USBR) Mogollon Mesa Project, Coconino County, Arizona and (3) the USBR Yellowhouse Project, Valencia County, New Mexico.

None of these projects are authorized or funded; thus they are assumed to have no impact upon future sediment production from the Basin. It is also assumed that existing projects will be maintained throughout their intended life span.

PROJECTED PROGRAMS

The agencies and programs related to erosion and sediment control are discussed in a later section of this report. Included are soil and water conservation and erosion control programs of the Natural Resource Conservation and Soil Conservation Districts, the Little Colorado River Plateau Resource Conservation and Development area, the Four Corners Regional Commission, the Indian tribes, the U.S. Bureau of Indian Affairs, the U.S. Bureau of Land Management, USDA's Soil Conservation Service, Forest Service and Agricultural Stabilization and Conservation Service, the states of Arizona and New Mexico, and agricultural and forestry research carried out by the U.S. Department of Agriculture, universities and private enterprise. These programs are assumed to continue at their present level.

Programs designed to reduce floodwater and sediment damage such as the flood control program of the Arizona Department of Water Resources and land use planning by all levels of government are assumed to continue. State laws and Federal laws such as the Clean Water Act (Public Law 95-217) and the National Environmental Policy Act will continue to provide regulations.

POPULATIONS PROJECTIONS

Projections of population and other socio-economic data are discussed in Appendix I, Section 2, SOCIO-ECONOMIC BASE. The Basin population is expected to increase to 245,900 in 1990; 303,700 in 2000; and 426,000 in 2020. There is also seasonal buildup in population, particularly during the peak

summer months, that puts additional pressure on natural resources. It is assumed that communities have the necessary land use controls to handle this development and a significant amount of increased erosion will not occur.

LIVESTOCK PROJECTIONS

Livestock projections are discussed in Appendix I, Section 2, SOCIO-ECONOMIC BASE. Cattle numbers are projected to have a slight increase (10 percent increase by 2020) and horses are projected to increase by 70 percent from 1975 to 2020. Sheep numbers are expected to decline. The total animal units for cows, sheep and horses is estimated as follows:

1975	179,000	animal units
1990	185,500	animal units
2000	189,900	animal units
2020	194,300	animal units

It is assumed that this increase in total animal units will not have a detrimental effect on vegetative cover or cause increased erosion.

PROJECTED LAND USE AND VEGETAL COVER

A summary of land areas by ownership and cover types is shown on Table 1-3. The Land Ownership and Administration Map shows the ownership pattern and the Vegetation Communities Map shows the pattern of vegetal cover. Major land uses are projected to remain unchanged except there may be shifts in ownership and grazing intensity of some of the rangelands as a result of the Navajo-Hopi Settlement Act.

Forestland

There are 6,724,450 acres of forestland in the Basin including 1,446,720 acres of coniferous forest and 5,277,740 acres of pinyon-juniper woodland. The total forestland acreage is 38.97% of the total land in the Basin, of which 2,075,770 acres (30.8%) is National Forest; 495,960 acres (7.38%) is administered by state and local governments; 2,528,470 acres (37.59%) are Indian lands; 436,120 acres (6.49%) is other Federal administration; and 1,188,140 acres (17.67%) is private ownership (see Table 1-3).

Land use factors that may impact upon erosion and sediment production from the forestlands include grazing, fire, recreation use, logging and change in use such as the designation of wilderness or roadless areas. Sediment production from the forestlands is not expected to increase above existing conditions. Recreation use is projected to increase, however, this will primarily occur in the coniferous forest where erosion is not a major problem. It is anticipated that the occurrence of forest fires will not change because the majority are caused by lightning, however, the average acres burned annually may decrease as fire fighting methods and equipment are improved. The U.S. Forest Service RARE II process identified 13 roadless areas encompassing 78,360 acres within the Basin. Congressional

Table 1-3: Summary of Land Areas by Cover Types and Related Categories, Little Colorado River Basin, Arizona and New Mexico

Cover Types and Related Categories	Private	National Forest	National Park Service	Indian Lands	Bureau of Land Management	Dept. of Defense	State and Local Government	Total
	Acres							
Alpine Tundra	0	1,500	0	0	0	0	0	1,500
Forest								
Coniferous forest	66,020	1,118,500	4,000	242,900	0	8,980	6,320	1,446,720
Pinyon-Juniper Woodland	1,122,120	957,270	23,000	2,285,570	388,200	11,940	489,640	5,277,740
Range								
Plains desert grassland	2,357,050	274,040	124,030	3,361,870	246,970	0	1,120,610	7,484,570
Great basin desert scrub	197,680	0	14,400	2,303,270	118,430	1,000	147,730	2,782,510
Mountain meadow grassland	3,800	12,400	0	0	0	0	0	16,200
Cultivated								
Irrigated	30,980	0	0	3,840	0	0	0	34,820
Dryland	4,200	0	0	0	0	0	0	4,200
Urban	19,000	0	0	4,000	0	0	0	23,000
Remote Subdivisions	180,000	0	0	0	0	0	0	180,000
Water	800	3,000	0	1,300	0	0	600	5,700
Total	3,981,650	2,366,710	165,430	8,202,750	753,600	21,920	1,764,900	17,256,960

1/ Includes Federal, private and trust lands (Indian lands).
2/ Unknown amount - included with private acres.
3/ Includes water surfaces having 40 acres or more of area and streams of 1/8-mile or more in width.

Source: Modified from the Lower Colorado Region Comprehensive Framework Study, Appendix VI.

action is required for final classification, therefore, these lands are assumed to remain in their current use for the future without plan condition.

Irrigated Land

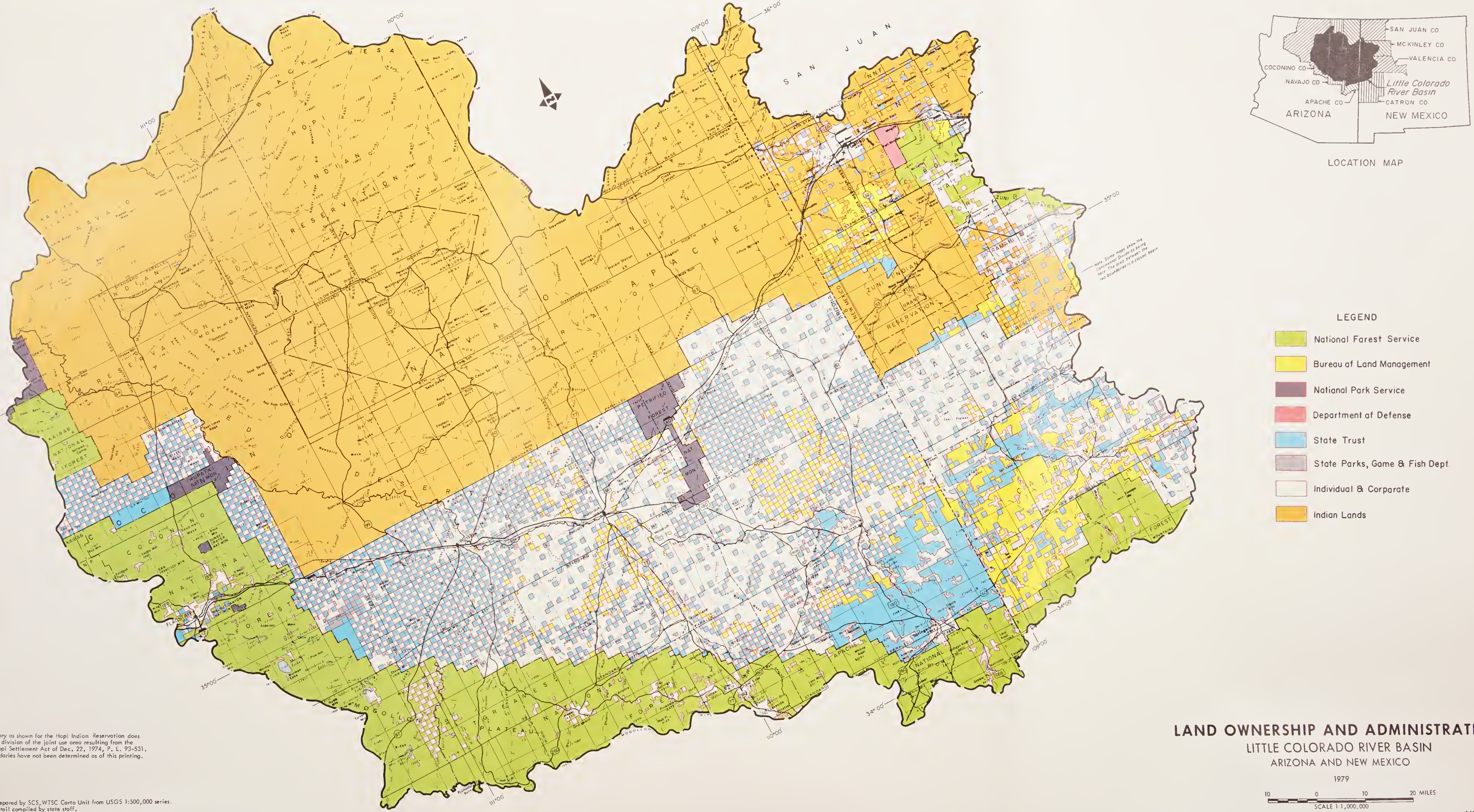
The irrigated lands comprise 34,820 acres, or about 0.20% of the total Basin. These lands do not contribute significantly to sediment production in the Basin, nor are they projected to do so in the future.

Rangeland

Excluding the mountain meadow grassland, there are 10,267,080 acres (59.50% of total Basin) of rangeland in the Basin, including 7,484,570 acres (43.37% of total Basin) of plains desert grassland and 2,782,510 acres (16.12% of total Basin) of great basin desert shrub. The majority of erosion and sediment delivered to the mouth of the Little Colorado River occurs on these lands. About 2,554,730 acres (24.88%) are private lands; 274,040 acres (2.67%) are National Forest lands; 138,430 acres (1.35%) are administered by the National Park Service; 5,665,140 acres (55.18%) are Indian lands; 365,400 acres (3.56%) are administered by the U.S. Bureau of Land Management; and 1,268,430 acres (12.36%) are state lands.

The future without plan conditions assumes that sediment production will not change from the National Forests or from the National Parks. Cover conditions on some of the public lands administered by the U.S. Bureau of Land Management are projected to improve as a result of implementation of the Federal Land Policy and Management Act of 1976 and the Public Rangelands Improvement Act of 1978. The state land is also projected to improve slightly due to stricter regulation in comparison with past years. The majority of the private lands are not projected to change significantly.

The greatest difficulty in projecting future conditions involves the Indian lands, which comprise 55.18% of the total rangeland and are projected to increase by another 400,000 acres when existing legislation is implemented. The Navajo-Hopi Settlement Act of December 22, 1974, Public Law 93-531, provides for final settlement of the Hopi-Navajo Joint Use Area by dividing the area between the Navajos and Hopis (see write up on Land Ownership in Appendix I, Section 1, DESCRIPTION OF BASIN). This act (Sec. 11) also authorized the transfer of up to 250,000 acres of lands under the jurisdiction of the Bureau of Land Management within the State of Arizona or New Mexico to the Navajo Tribe, provided that the Tribe pay to the United States the fair market value for such lands. This land was intended for the relocation of Navajo families from the Joint Use Area. The land that was selected for transfer was on the Paria Plateau in Arizona, just north of the Colorado River, and not within the Little Colorado River Basin. In 1980, the act was amended by Public Law 96-305 (July 8, 1980) whereas the Navajo Tribe now attains up to 250,000 acres of public land free with the option to buy another 150,000 acres. This land cannot be north or west of the Colorado River nor can more than 35,000 acres be in New Mexico. Further, the land must be within 18 miles of the 1934 Reservation Boundary.



Note:
The boundary as shown for the Hopi Indian Reservation does not reflect division of the joint use area resulting from the Navajo-Hopi Settlement Act of Dec. 22, 1974, P. L. 93-531. Final boundaries have not been determined as of this printing.

LAND OWNERSHIP AND ADMINISTRATION

LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

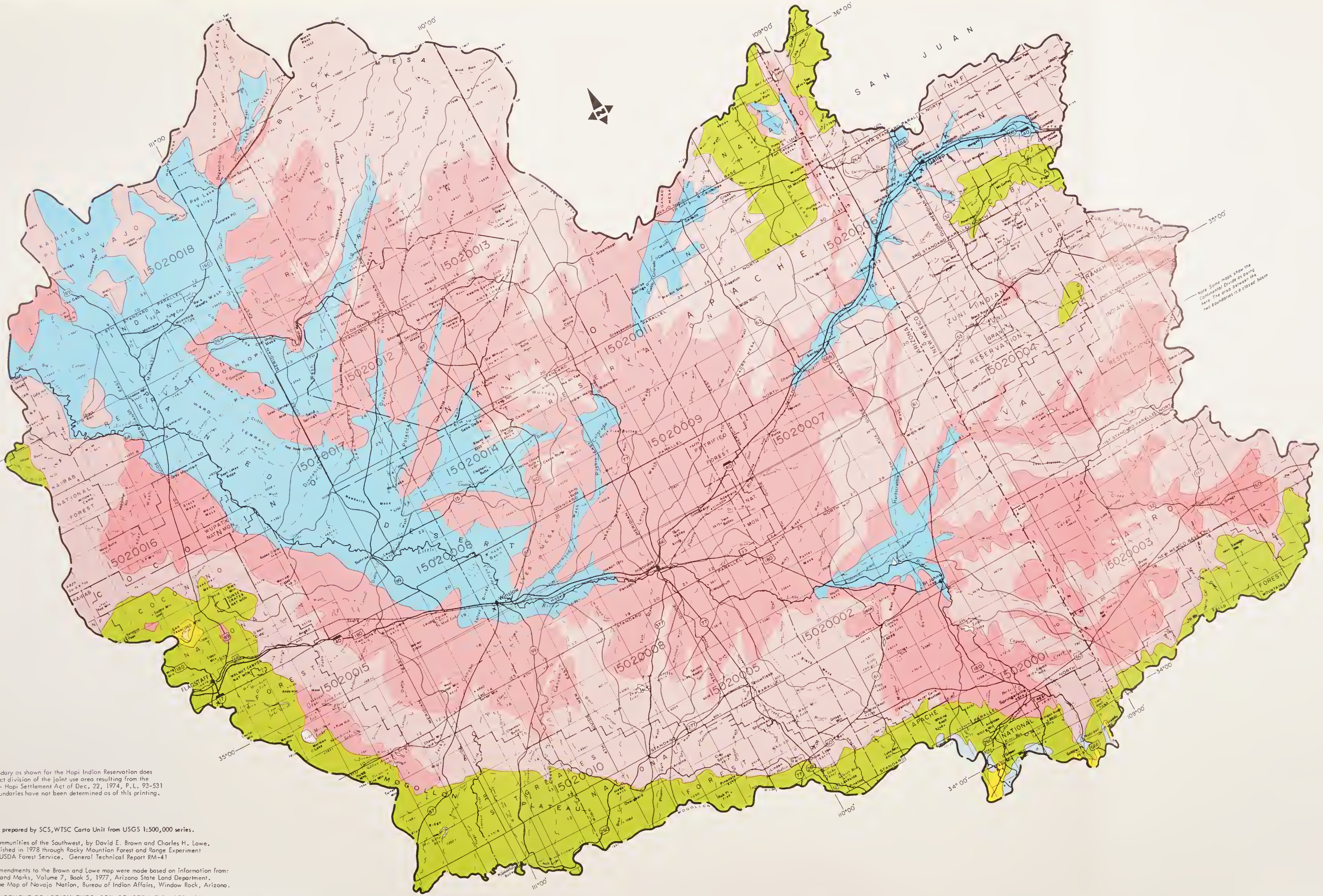
1979

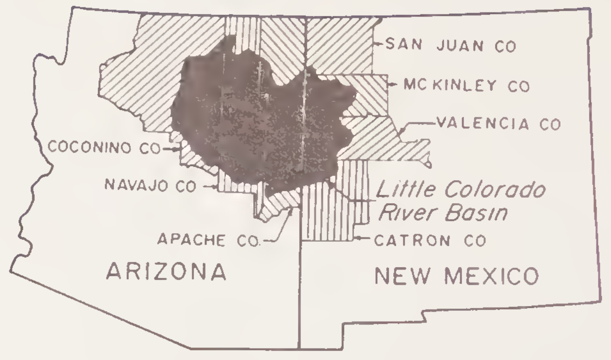
10 0 10 20 MILES
SCALE 1:1,000,000

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.
Thematic detail compiled by state staff.

U.S DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND OR 1980

M7-EN-23833-1





LOCATION MAP

LEGEND

- Alpine Tundra
- Spruce-Alpine Fir Forest
- Montane Conifer Forest
- Juniper-Pinyon Woodland
- Plains and Desert Grassland
- Mountain Meadow Grassland
- Great Basin Desert Scrub

15020004 Hydrologic Unit Code
US Water Resource Council

NOTE: Description of vegetation communities are in the Fish and Wildlife Section of the report.

Note:
The boundary as shown for the Hopi Indian Reservation does not reflect division of the joint use area resulting from the Navajo - Hopi Settlement Act of Dec. 22, 1974, P.L. 93-531
Final boundaries have not been determined as of this printing.

Source:
Base map prepared by SCS, WTSC Carto Unit from USGS 1:500,000 series.

Biotic Communities of the Southwest, by David E. Brown and Charles H. Lowe. Map published in 1978 through Rocky Mountain Forest and Range Experiment Station, USDA Forest Service. General Technical Report RM-41

Several amendments to the Brown and Lowe map were made based on information from:
Arizona Land Marks, Volume 7, Book 5, 1977, Arizona State Land Department.
Forest Type Map of Navajo Nation, Bureau of Indian Affairs, Window Rock, Arizona.

VEGETATION COMMUNITIES
LITTLE COLORADO RIVER BASIN
ARIZONA AND NEW MEXICO

1980

10 0 10 20 MILES
SCALE 1:1,000,000

U S DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE USDA-SCS-PORTLAND OR 1980

M7-EN-23833-8

As of this writing, the selection of this land has not been made. There is strong possibility that the land will be within the Little Colorado River Basin, although there is not enough public land (see Land Ownership Map) within an 18 mile distance of the reservation boundary to meet all of the criteria contained in P.L. 96-305. An option is to exchange public land elsewhere in the state of Arizona for private lands contiguous to the reservation, then transfer the public land to the Navajos.

It is difficult to accurately predict the final outcome of the Navajo-Hopi Settlement Act. It is also difficult to predict future grazing policies on the Navajo Reservation. The Tribal Council has proposed grazing fees on several occasions, however, these proposals have been defeated. The future outcome is uncertain.

For the purpose of this report, USDA assumes that all or part of the 400,000 acres authorized for transfer to the Navajos will be within the Little Colorado River Basin. Further, there may be a decrease in vegetation on these lands due to increased grazing and wood gathering; thus creating a greater potential for erosion. However, this will be offset by improvements in some of the old Joint Use Area due to decreased population and grazing pressure.

ALTERNATIVE PLANS

USDA Procedures for Planning Water and Related Land Resources were used to evaluate potential measures to reduce erosion, sediment and salt contribution to the Colorado River. These procedures identify the two broad national objectives of National Economic Development (NED) and Environmental Quality (EQ). Two alternative plans, an NED Plan and an EQ Plan, directed toward satisfying each of these objectives, were formulated. No other alternative plans were prepared. Both plans are made up of land treatment practices; structural measures are not included. In general terms, the NED plan is directed toward increasing the output of goods and services and efficiency gains. The EQ plan is directed toward enhancing environmental quality by the management, conservation, preservation, creation, restoration or improvement of certain natural and cultural resources and ecological systems.

Resource improvement objectives include: reduced soil erosion, protect water quality, improve the productive capacity of the natural resources, improve wildlife habitat, improve esthetics, improve the standard of living for residents of the area and for those people who use and depend on the products from the natural resources.

DATA COLLECTION

In the Arizona portion of the Basin, sites were selected based on diversity of soil mapping units, vegetative types, erosion conditions, land use variations, etc. The rationale was to sample rangeland conditions under as many representative situations as possible. The sites are also being used in a national resource inventory being conducted by the Soil Conservation Service.

About 200 of these sites were field studied by conservationists stationed in the area and familiar with local conditions. The SCS led the data collection assisted by the U.S. Forest Service and U.S. Bureau of Indian Affairs. A worksheet was used to collect consistent data (see next page). Soil samples were taken at some sites for laboratory analysis to determine salt content. The Universal Soil Loss Equation was used to determine sheet and rill erosion rates. Estimates were made of streambank and gully erosion. The erosion rates were added, a delivery ratio applied, and sediment yields and salt loadings estimated.

Field data from the sites were summarized according to soil mapping units 1/ and major land resource areas. This represented a set of field observations for each soil map unit. Other sites were not field studied but were added to the evaluation on a judgment basis.

The size of the soil mapping unit was determined by planimeter. The percent of each range site in each soil mapping unit and the extent of each range condition class was estimated and this data was expanded to the entire Basin. This process was the basis for development of Resource Management Systems and the effects of applying these systems, both in terms of increased production of forage and a reduction in erosion.

In New Mexico, the Basin was aggregated to nine range site associations. Each of these is characterized by a soil mapping unit and a plant ecosystem. Each association has similar problems and would require similar treatment.

RESOURCE MANAGEMENT SYSTEMS

The land treatment program is a "resource management system" made up of components (elements) of individual conservation practices. Included are small structural type measures such as gully plugs and erosion control dams, and management measures such as range proper use and fencing of small ponds.

The field inventories were used as the basis for determining which conservation practices would be practical. The elements of the Resource Management System (see Tables 1-5 and 1-6) are based on the inventory and on the following assumptions:

1. Most of the land in the Basin is in native vegetation and is grazed by livestock to some extent. Eighty percent of the area provides forage and is grazed. The remaining areas are badlands with little vegetation, towns, cropland, roads, utilities and other land uses not normally grazed. These values are based on area measurement of relatively small scale maps and by field observation from ground level and airplane.

2. All grazeable land in "poor" and "fair" range condition needs treatment and will respond to proper grazing use and planned grazing systems. The latter includes the installation of fences and watering

1/ Refer to Appendix I, Section 1, DESCRIPTION OF BASIN, for information on the soils in the Basin.

RANGE CONDITION WORKSHEET

RANCH: ______________________ RANGE SITE: ______________________

LOCATION: ______________________ CONSERVATIONIST: ______________________

MLRA: ______________________ DATE: ______________________

Vegetation

Plant Groups	Plant Names	Percent Present	Percent Climax
Grasses and Grass-like Plants			
____%			
Forbs			
____%			
Shrubs and Trees			
____%			
100%	TOTALS	100%	

Ground Cover:	Percent
Grasses and forbs:	
Shrubs and trees:	
Litter:	
Rock and gravel:	
Bare ground:	

Range Trend

Plant Vigor:	High	Med.	Low

Plant Spread:	Much	Some	None

Plant Residues:	Much	Some	None

Soil Surface Conditions:

Bare ground	Much	Normal	None
Soil crusting	Much	Some	None
Rock or gravel	Much	Some	None
Plant hummocks	Much	Some	None
Soil movement	Much	Some	None

Final Trend Rating:
- Upward ______________
- Holding steady ______________
- Downward ______________

Final Range Condition Class: ______________________

Estimated total production: ______________________

Production of forage species: ______________________

Description of growing season: ______________________

____

Vegetation, facilitating or accelerating practices needed to improve this range:

____

____

____

Estimated extent of site & other comments:

____

____

____

1/ Range sites are those areas which have the potential for producing similar amounts and kinds of vegetation. Sites are determined by climate, soil, topographic and vegetational features.

facilities, and the management of the forage includes deferred grazing and proper grazing use. It is also necessary to maintain that status on "good and excellent" range conditions.

3. Water spreading is site specific and must be designed to solve the problems in each area individually. It was assumed that one-fifth of all clay bottom, loamy bottom, clay fan, clay loam upland and clay upland range sites on slopes about one percent or less and in poor condition would respond with several times more production. Other range sites will also respond but must be checked locally.

4. Brush management is assumed to be effective in areas where a poor diversity of plant cover and encroachment of woody species is present.

5. Prescribed burning is effective where woody species can be reduced by carefully controlled fires.

6. Range seeding is assumed to be necessary where all perennial native forage species have been eliminated. Native grasses, forbs and shrubs are included in these seedings.

7. Deferred grazing is necessary for two or more years after range seeding or burning has occurred. It is also necessary in the planned grazing system component.

8. Mechanical treatment, such as pitting, furrowing or chiseling, is assumed to be effective where fine textured soils with vegetation in poor condition are present. These practices help to make a better seedbed for range seeding and in getting precipitation to enter the soil where it may be stored for plant growth.

9. It was assumed that livestock will need water developments within one-half mile of forage on rough terrain and within about one mile on smooth or undulating terrain.

EFFECTS OF APPLYING RESOURCE MANAGEMENT SYSTEMS

The estimated effects of applying the Resource Management Systems for the Arizona portion of the Basin are shown below:

	Area in Acres (Arizona)		
Range Condition	1990	2000	2020
Fair and poor condition, without program.	5,874,900	5,865,400	5,849,600
Fair and poor condition, with program.	5,581,200	4,692,300	2,632,300
Good and excellent condition, with program.	293,700	1,173,100	3,217,300

Projections are that range condition shifts from poor-fair to good-excellent will generally increase the diversity, vigor and number of close growing grasses and forbs amongst fewer trees and shrubs and on areas of low density vegetation. Such a response will result in higher forage production and a decreased opportunity for the occurrence of erosion.

In New Mexico, three levels of management (high, medium and low) were specified for present and future conditions. The percentage of land in each management level by time frame was specified. These percentages are shown in the following tabulation:

PERCENT OF LAND IN EACH OF THREE MANAGEMENT LEVELS BY TIME FRAME
LITTLE COLORADO RIVER BASIN, NEW MEXICO

Management Level	Present Condition	Future Without 1990	Future Without 2000	Future Without 2020	Future With 1990	Future With 2000	Future With 2020
Low	60%	55%	50%	45%	40%	30%	20%
Medium	30%	30%	30%	30%	30%	30%	30%
High	10%	15%	20%	25%	30%	40%	50%

The management levels shown are tied to range condition classes in the following manner:

Management Level	Range Condition Class
Low	Poor to fair
Medium	Fair to good
High	Good to excellent

Estimates and calculations of production cost, return, animal unit months, erosion, etc., were made for each range site by time frame by management level for present and future conditions.

ECONOMIC AND ENVIRONMENTAL ANALYSIS

The alternative plans are composed of land treatment practices only. Costs of applying the land treatment practices shown in NED Plan A and EQ Plan B were estimated based upon experience with installing practices within the Basin. Project installation costs use a 1980 base. Average annual costs were computed using a discount rate at 7 3/8 percent interest for 50 years.

Three types of increased net income benefits were evaluated: increased forage from improved range condition, reduced salinity in the Colorado River and unemployed labor resources.

The economic analysis is directly related to the physical data obtained from the field studies discussed previously. Representative cost-return budgets were developed for present and future conditions and for each alternative range management system. The approach was to relate pounds of usable forage to the net returns from the sale of beef. This was done by

ten pound increments of usable forage for each field site within each of several soil mapping units. Adjustments were made in the representative budget to depict production that would exist should the various alternatives of range management and programs be applied. These changes modified the original budget. Therefore, budgets were developed to reflect those changes associated with various levels of production. These methods appear to fit the overall evaluation for the Basin, and is a way to compute the beneficial and adverse effects of the various alternatives studied.

Benefits from reduced salinity in the Colorado River are related to salinity levels at Imperial Dam. At a value of $52 per ton of salt, the existing damages from salinity contributed by the Basin are about $3.7 million dollars per year. Plans A and B would reduce salinity in the Colorado River by about 9,000 tons per year, or about $468,000 per year at $52 per ton.

The development of the EQ Plan B for this study is subjective. Any environmental quality plan is value-laden because of the multitude of values that can be addressed: archeological resources, historical resources, water quality, air quality, scenic value, wildlife, areas of natural beauty, etc. The primary thrust of the EQ Plan presented in this report is toward the maintenance and improvement of wildlife habitat, esthetics and improvement of the land resource base.

NED PLAN A

The NED Plan emphasizes a program to produce things needed by the population of our country with as low a cost of production as possible.

The NED requires more pressure on natural resources if the demand for goods is high. However, the natural resources are protected from deterioration if possible in meeting the demand for goods and services.

Table 1-4, Existing and Projected Needs for Rangeland Resource Improvement Needs, is the basis for the NED Plan A. The NED Plan, shown as a Resource Management System, is on Table 1-5. Emphasis is on production of forage, but with a reduction in erosion rates where possible.

This plan will require considerable increase in financial and technical assistance effort. The measures are practical, can be applied and will cause the effects claimed. This will not be accomplished however without a great effort. The technology is available but must be applied by trained personnel; it requires changes in the traditional methods of doing work. People will make changes if the problems are clear and they have some confidence in the solutions presented.

EQ PLAN B

The EQ Plan B is shown on Table 1-6. The general approach to safe grazing is to use one-half and leave one-half of the growth of forage annually. In the case of the EQ Plan, more vegetation is left for wildlife. Generally, 60 percent of the annual growth is left. This increases the

TABLE 1-4

EXISTING AND PROJECTED RANGELAND RESOURCE IMPROVEMENT NEEDS,
WITHOUT ACCELERATED PROGRAM,
LITTLE COLORADO RIVER BASIN, ARIZONA AND NEW MEXICO

PRACTICE	UNIT	AMOUNT NEEDED BY TIME FRAME			
		EXISTING	1990	2000	2020
Proper Grazing Use	Acre	8,638,000	8,628,700	8,614,800	8,601,000
Planned Grazing System	Acre	8,638,000	8,628,700	8,614,800	8,601,000
Fence	Mile	4,600	4,600	4,500	4,500
Water Spreading	Acre	357,100	356,700	356,100	355,200
Brush Management	Acre	3,823,000	3,818,900	3,814,800	3,810,700
Range Seeding	Acre	1,426,900	1,425,400	1,423,100	1,419,300
Prescribed Burning	Acre	995,900	994,900	994,300	991,600
Deferred Grazing	Acre	4,670,000	4,665,000	4,657,500	4,644,900
Mechanical Treatment	Acre	1,009,900	1,008,800	1,007,200	1,004,400
Stock Water Developments	Number	6,900	6,600	6,200	5,900

TABLE 1-5

ELEMENTS OF THE RANGELAND RESOURCE MANAGEMENT SYSTEM - NED PLAN A

ITEM	UNITS	AMOUNT
Proper Grazing Use	Acres	7,896,000
Deferred Grazing	Acres	4,264,000
Planned Grazing System	Acres	7,896,000
Fence	Miles	3,000
Water Spreading	Acres	224,000
Brush Management	Acres	3,043,000
Range Seeding	Acres	894,000
Prescribed Burning	Acres	587,000
Mechanical Treatment	Acres	633,000
Stock Water Development	Number	4,000

TABLE 1-6

ELEMENTS OF THE RANGELAND RESOURCE MANAGEMENT SYSTEM - EQ PLAN B

ITEM	UNITS	AMOUNT
Proper Grazing Use	Acres	7,896,000
Deferred Grazing	Acres	4,264,000
Planned Grazing System (Livestock use restricted to 40% of annual forage growth. Wildlife considered as land users.)	Acres	7,896,000
Fence 1/ (Bottom wire to be smooth in deference to antelope habits.)	Miles	3,000
Water Spreading (Seed forbs and grasses upslope)	Acres	224,000
Brush Management (Emphasis on maximum wildlife habitat development and enhancement.)	Acres	3,043,000
Range Seeding (Includes forbs, shrubs and special category species.)	Acres	894,000
Prescribed Burning	Acres	587,000
Mechanical Treatment	Acres	633,000
Stock Water Development 2/	Number	4,000
Restricted area for wildlife (fenced)	Acres	25,000
Wetland improvement (fenced)	Acres	1,900

1/ Does not include 1671 miles of stock pond fencing.
2/ Assumes 2 to 1 development of ponds vs. wells, springs, etc.

vigor and density of plants to improve the esthetics of the area. Other elements in the EQ alternative include the use of smooth wire on the bottom of barbed wire fences to allow wildlife freedom to roam; creating wildlife habitat around ponds; providing a variety of seed for better food and cover for wildlife when applying the range seeding practice; leaving strips of brush for wildlife when vegetation is removed; and fencing portions of the stock water developments and wetland for wildlife.

IMPACTS OF ALTERNATIVE PLANS

The combined impacts of the alternative plans are shown in Tables 1-7 through 1-10. The information shown in these tables is summarized below:

TABLE NUMBER	PLAN	ACCOUNT
1-7	NED Plan A & EQ Plan B	National Economic Development
1-8	NED Plan A & EQ Plan B	Environmental Quality
1-9	NED Plan A & EQ Plan B	Regional Development
1-10	NED Plan A & EQ Plan B	Social Well Being

The sensitivity to varying levels of resource development in the alternatives is subjective and is complicated by management problems facing today's ranchers.

TABLE 1-7

LITTLE COLORADO RIVER BASIN

NATIONAL ECONOMIC DEVELOPMENT ACCOUNT-PLANS A&B

COMPONENT	Measure of Effects (Average Annual)	
	Plan A - NED	Plan B - EQ
Income:		
Beneficial Effects:		
A. The value to users of increased outputs of goods and services 1/		
1. Increased range grazing	$14,601,600	$11,093,400
2. Reduced salinity in the Colorado River	468,000	468,000
3. Unemployed Labor Resources	272,700	285,600
Total Beneficial Effects	$15,342,300	$11,847,000
Adverse Effects:		
A. The value of resources required for the plan 2/		
1. Rangeland treatment systems		
a. Project installation	$ 8,308,200	$ 8,714,000
b. OM&R	2,340,700	2,508,000
c. Technical assistance	374,300	447,300
Total Adverse Effects	$11,023,200	$11,669,300
Net Beneficial Effects	4,319,100	177,700

1/ Price Base: Current normalized prices for increased range grazing; 1980 prices for others.

2/ Discount rate @ 7 3/8 percent for 50 years.

TABLE 1-8

LITTLE COLORADO RIVER BASIN

ENVIRONMENTAL QUALITY ACCOUNT - PLANS A&B

COMPONENT	Measure of Effects	
	Plan A - NED	Plan B - EQ
Beneficial and Adverse Effects:		
A. Areas of Natural Beauty	1. Visual impact of fire and mechanical control of trees and other brush on about 5,792,600 acres of grazing land.	1. Same as Plan A
	2. Visual effect in appearance of landscape with increase of grass forbs, non-woody schrubs and special category species on about 7,896,000 acres of grazing land.	2. Same as Plan A
	3. Visual effect of changing about 5,792,600 acres of tree and brush dominated grazing land to more open grassland.	3. Same as Plan A
	4. Visual impact of water-spreading structures spaced as needed on about 224,000 acres of grazing land.	4. Same as Plan A
	5. Visual effect of increase in surface water and associated vegetation with construction of about 4,000 stocks ponds.	5. Same as Plan A, except stockponds are fenced
	6. Visual impact of newly constructed, stock ponds dotting the landscape.	6. Same as Plan A, except stock ponds are fenced.
	7. Interruption of the landscape by increase in fencing across grazing land.	7. Same as Plan A
		8. Visual effect of patterns of juniper-pinon and other brush management for consideration of wildlife as equal users of grazing lands.

TABLE 1-8

LITTLE COLORADO RIVER BASIN

ENVIRONMENTAL QUALITY ACCOUNT - PLANS A&B
(CONTINUED)

COMPONENT	Measure of Effects	
	Plan A - NED	Plan B - EQ
Beneficial and Adverse Effects:	1. Gradual reduction of soil erosion over about 7,896,000 acres of grazing land.	1. Same as Plan A
B. Quality considerations of water, land and air resources	2. Increase the kinds, amount and vigor of vegetation on about 7,896,000 acres of grazing land.	2. Increase diversity and vigor of vegetation on about 7,896,000 acres and (include seeding of species usable by wildlife).
	3. Increase the distribution of surface water by constructing about 4,000 stock ponds.	3. Same as Plan A
	4. Reduce blowing dust from areas that will support vegetation by increasing the amount of protective vegetation and litter on the soil surface.	4. Same as Plan A
	5. Increase infiltration rate on about 645,300 acres of grazing land.	5. Same as Plan A
	6. Reduce sediment load of the Little Colorado River by about 3.95 million tons per year.	6. Same as Plan A
	7. Reduce salt load of the Little Colorado River by about 9,000 tons per year.	7. Same as Plan A
	8. Increase short term wind and water erosion hazard in locations of: a. Prescribed burning b. Brush management by root plowing, dozing, or other surface disturbance. c. Newly constructed ponds water spreaders or other earthen structures.	8. Same as Plan A
	9. Increase short term degradation of air quality by dust and/or smoke from practices listed in Effect 8.	9. Same as Plan A

TABLE 1-8

LITTLE COLORADO RIVER BASIN

ENVIRONMENTAL QUALITY ACCOUNT - PLANS A&B
(CONTINUED)

COMPONENT	Measure of Effects	
	Plan A - NED	Plan B - EQ
B. (continued)		10. Decrease turbidity of stock water by fencing out livestock and providing drinkers or limited access to ponds.
		11. Increase biomass and vigor of forage species by restricting grazing to 40% of current year's growth.
C. Biological Resources and selected ecosystems.	1. Increase in amount and diversity of vegetation for livestock on about 7,896,000 acres will be of general benefit to Basin wildlife species.	1. Increase in amount and diversity of vegetation for livestock and wildlife on about 7,896,000 acres will be of direct benefit to wildlife species.
	2. Additon of about 4,000 stock ponds to increase seasonal waters will be of general benefit to land dwelling species and may provide seasonal resting areas for water fowl.	2. Addition of about 4,000 fenced tock ponds to increase seasonal waters will be of general benefit to wildlife species by establishing about 25,000 acres of water associated habitat.
	3. Addition of about 1,300 permanent water developments will be of specific benefit to larger mammals, climbing mammals and reptiles, arthropods and certain birds.	3. Same as Plan A
	4. Restriction of free ranging habits of deer, elk, & antelope. by additional cross fences on grazing land.	4. Same as Plan A
	5. A general reduction of juniper-pinyon and shrub dominated habitat type with eventual increase in grassland habitat type.	5. Same as Plan A

TABLE 1-8

LITTLE COLORADO RIVER BASIN

ENVIRONMENTAL QUALITY ACCOUNT - PLANS A&B
(CONTINUED)

COMPONENT	Measure of Effects	
	Plan A - NED	Plan B - EQ
C. (continued)	6. A general reduction in value of some habitats will occur as brush management is carried out.	6. Same as Plan A
	7. Possible harm to animals during construction.	7. Same as Plan A
		8. In antelope range, smooth bottom wire on grazing land and stock pond fences will mitigate somewhat the restrictive nature of barbed wire.
		9. Seeding pond edges, allowing native vegetation to grow and restricting grazing in the fenced portion will provide direct benefits to waterfowl and other species that need cover.
		10. General increase in value of juniper-pinyon brush management is undertaken to provide consideration to wildlife as a user of grazing land.
D. Irreversible or irretrievable commitments.	1. Commitment of land, water, labor, and monetary resources to manmade features such as stock ponds, wells, erosion control structures, water spreaders, etc.	1. Same as Plan A
		2. Commitment of land, water, labor and monetary resources to about 25,000 acres of livestock excluded area nearly surrounding about 4,000 stockponds for establishing and/or enhancing upland and wetland habitat; and to locate livestock drinking facilities and/or access ways in keeping with wildlife habitat needs.

TABLE 1-9

LITTLE COLORADO RIVER BASIN

REGIONAL DEVELOPMENT ACCOUNT - PLANS A&B

COMPONENT	Measure of Effects (Average Annual)			
	Plan A - NED		Plan B - EQ	
	Little Colorado River Basin	Rest of Nation	Little Colorado River Basin	Rest of Nation
Employment:				
Beneficial Effects:				
A. Increase in number and types of jobs.				
1. Employment for rangeland treatment construction	315 2/ unskilled jobs, 2/ 179 2/skilled jobs, 52 semi-skilled jobs.	-	331 1/ unskilled jobs, 188 skilled jobs, 55 semi-skilled jobs.	-
2. Employment for rangeland treatment OM&R	Permanent full-time jobs: 55 unskilled, 2 skilled and 1 semi-unskilled job.	-	Permanent full time jobs: 61 unskilled, 3 skilled and 1 semi-skilled jobs.	-
Total Beneficial Effects	546 2/ employment during the construction period and 58 permanent full-time jobs in OM&R.	-	574 1/ employment during the construction period and 65 permanent full-time jobs in OM&R.	-
Adverse Effects:				
A. Decrease in number and types of jobs.	-	-	-	-
Total Adverse Effects	-	-	-	-
Net Beneficial Effects	546 2/ employment during the construction period and 58 permanent full-time jobs in OM&R	-	574 1/ of employment during the construction period and 65 permanent full-time jobs in OM&R	-
Population Distribution:				
Beneficial Effects:	Creates 58 permanent full-time jobs in predominantly rural river basin area that has experienced a 28 percent increase in population from 1970-1977.	0	Creates 65 permanent full-time jobs in the predominantly rural river basin area that has experienced a 28 percent increase in population from 1970-1977.	0

TABLE 1-9

LITTLE COLORADO RIVER BASIN

REGIONAL DEVELOPMENT ACCOUNT - PLANS A&B
(CONTINUED)

COMPONENT	Measure of Effects (Average Annual)			
	Plan A - NED		Plan B - EQ	
Population Distributed: (cont.)	Little Colorado River Basin	Rest of Nation	Little Colorado River Basin	Rest of Nation
Adverse Effects:	0	0	0	0
Regional Economic Base and Stability:				
Beneficial Effects:	Creates 58 permanent 1/ full-time jobs and 546 construction employment in the river basin area. This area has an unemployment rate of 8 percent. About 50 percent of the needed treatment measures are the Navajo and Hopi Indian Reservations. These reservations have an unemployment rate of about 65 percent, August 1978.	0	Creates 65 permanent 1/ full-time jobs and 574 of construction employment in the river basin area. This area has an unemployment rate of 8 percent. About 50 percent of the needed treatment measures are on the Navajo and Hopi Reservation. These reservations have an unemployment rate of about 65 percent, August 1978.	
Adverse Effects:	0	0	0	0

TABLE 1-9

LITTLE COLORADO RIVER BASIN

REGIONAL DEVELOPMENT ACCOUNT - PLANS A&B
(CONTINUED)

COMPONENT	Measure of Effects (Average Annual)			
	Plan A - NED		Plan B - EQ	
			Measures of Effects	
	Little Colorado River Basin	Rest of Nation	Little Colorado River Basin	Rest of Naion
Income:				
Beneficial Effects:				
A. The value of increased output of goods and services to users. 1/				
1. Increased range grazing	$14,601,600	-	$11,093,400	-
2. Reduced salinity in the Colorado River		$ 468,000	-	$468,000
3. Unemployed labor resources	272,700	-	285,600	-
Total Beneficial Effects	$14,874,300	$ 468,000	$11,379,000	$468,000
Adverse Effects:				
A. The value of resources required for the plan. 2/				
1. Rangeland treatment systems				
a. Project installation	$ 2,971,600	$5,336,600	$ 3,073,000	$5,641,000
b. OM&R	2,340,700	-	2,508,000	-
c. Technical assistant	-	374,300	-	447,300
Total Adverse Effects	$ 5,312,300	$5,710,900	$ 5,581,000	$6,088,300
Net Beneficial Effects	$ 9,562,000	$-5,242,900	$ 5,798,000	$-5,620,300

1/ Price Base: current normalized prices for increased range grazing; 1981 prices for others.

2/ Discount rate @ 7 3/8 percent for 50 years.

TABLE 1-10: LITTLE COLORADO RIVER BASIN, PLANS - A&B

Social Well-Being Account

Measures of Effects

Plan A - NED

Beneficial and Adverse Effects
Real Income Distribution

1. Creates 58 low to medium income, permanent full-time jobs for area residents.

2. Creates regional income benefit distribution of $14,874,300 by income class as follows:

Income Class (Dollars)	Percentage of Persons With Adjusted Gross Income in Class	Percentage Benefits In Class
$3,000	24.3	50.9
$3,000-$10,000	43.5	28.2
$10,000	32.2	20.9

3. Local costs to be borne by region total $5,312,300 with distribution by income class as follows:

Income Class (Dollars)	Percentage of Persons With Adjusted Gross Income in Class	Percentage Contributions In Class
$3,000	24.3	50.1
$3,000-$10,000	43.5	28.7
$10,000	32.2	21.2

Plan B - EQ

1. Creates 65 low to medium income, permanent full-time jobs for area residents.

2. Creates regional income benefit distribution of $11,379,000 by income class as follows:

Income Class (Dollars)	Percent of Persons With Adjusted Gross Income In Class	Percentage of Benefits In Class
$3,000	24.3	51.3
$3,000-$10,000	43.5	28.0
$10,000	32.2	20.7

3. Local costs to be borne by region total $5,581,000 with distribution by income class as follows:

Income Class (Dollars)	Percent of Persons With Adjusted Gross Income in Class	Percentage of Contributions In Class
$3,000	24.3	50.1
$3,000-$10,000	43.5	28.7
$10,000	32.2	21.2

STRUCTURAL CONSIDERATIONS

The term "structural measures" as defined and used in this report includes four types of erosion control practices: retention dams, detention dams, grade stabilization structures and structural streambank protection measures. Other practices such as water spreaders and stock ponds that are often classified as "structural" by some authorities are included in the land treatment section of this report. The NED and EQ plans previously discussed in this report do not include any structural measures. Structures are of such demanding nature that studies must be intense and site specific in order for planners to have confidence in structural feasibility. The degree of study required for the entire Basin is beyond the limited resources available to USDA for this river basin study. Several sites were studied where structural treatment is the obvious remedy, but these proved to be economically unfeasible. Nevertheless, structures are an essential part of any erosion control program. Structures do have a role. It should not be inferred that structural measures are not needed in this Basin.

This section discusses some of the successes and failures of structures constructed in the past and gives recommendations for the future.

RETENTION/DETENTION DAMS

Retention dams are structures that retain all inflow until the reservoir storage reaches the spillway level at which time outflow occurs through the spillway. A detention dam differs from a retention dam in that it has an outlet pipe through which inflow is released downstream at a controlled rate.

Retention and detention dams can be very effective in controlling erosion. There is no other erosion control practice that affords the advantages of a large dam in reducing flood peaks while at the same time controlling erosion and inducing sediment deposition in the stream channel upstream of the dam. However, retention and detention dams must be properly located, designed and constructed. The greatest drawback of a reservoir is its high sediment trap efficiency. Structures that are not designed to account for sediment accumulations, particularly in high sediment yield areas, will be short lived. Spillway design and construction is a critical feature. The spillway must be designed to pass flood flows and it must be non-erosive to prevent breaching. The frequency of spillway operation increases over time as sediment accumulations reduce reservoir storage. The spillway must continue to function without costly or frequent maintenance.

There are several large retention dams within the Basin that provide testimony to the effectiveness of reservoir structures. One is Zion Dam (Udall Reservoir) located across the main stem of the Little Colorado River about ten miles northwest of St. Johns in Apache County, Arizona (see Photo 1-21). The original dam was built in 1902-1905 as an irrigation reservoir but was destroyed by a flood; a second dam was finished in 1908 and failed in 1916 when the upstream Lyman Dam failed; a third dam was

completed in 1919 and stood until failure in 1973; the present dam was completed in 1979. Studies made by the U.S. Bureau of Reclamation (1955) show that in the 44 year period (1908-1952) about 22,700 acre-feet of sediment have been deposited above Zion Dam. The dam has caused sedimentation as far upstream as the U.S. Highway 666 crossing over Carrizo Wash, which is about 11 miles upstream from the dam and 80 feet higher than the elevation of the dam spillway.

Photo 1-21. Zion Dam, Apache County, Arizona. Aerial view looking east (upstream) showing failed dam and sediment. The dam failed in 1973; repaired in 1979.

Another structure is Polacca Wash Dam No. 2, located across Polacca Wash on the Hopi Indian Reservation about six miles southwest of the Village of Polacca, Navajo County, Arizona. Between about 1900 and 1945 the channel of Polacca Wash eroded to a depth of about 40 feet near Polacca (Hadley, 1963). In the years 1945 to 1953, three dams, designated as Numbers 1, 2 and 3 (Hadley), were constructed on Polacca Wash and another near the mouth of Wepo Wash. The purpose of these structures was to direct flood flows out for water spreading over the valley floor and to induce deposition of sediment in the channel.

Polacca Dam No. 3, the downstream structure, was built in 1946. Polacca Wash is entrenched 38 feet at the site. The crest of the dam is 48 feet above the streambed. Hadley reports that sediment has accumulated behind this barrier to a depth of 38 feet and completely filled Polacca Wash for 9,030 feet upstream. USDA viewed this dam in November 1980. The structure

has failed through the emergency spillway and a large headcut is advancing through the sediments.

Polacca Dam No. 2, constructed in 1945, is about 49 feet above the streambed which is about 40 feet deep (see Photo 1-22). Sediment has almost completely filled the reservoir area above this barrier (see Photo 1-23) and deposition extends several miles upstream. The reservoir area has been reclaimed by dense stands of vegetation (see Photo 1-24). USDA also viewed this dam in November 1980. A large headcut is advancing through the emergency spillway.

Polacca Dam No. 1, the upper dam, was completed in 1953 and is located just below the confluence of Polacca Wash with Burnt Corn Wash and Low Mountain Wash. Hadley (1963) reports that the channel has been completely filled above the structure for a distance of 2,300 feet and channel deposits extend upstream for 7,500 feet. USDA visited this site in 1979. The dam has been breached (see Photo 1-25) and is no longer functional.

Photo 1-22. Polacca Wash Dam No. 2, Hopi Indian Reservation, Navajo County, Arizona. Aerial view looking southeast showing Polacca Wash downstream of dam. Main dam to left of photo. Dikes in center are bays in the emergency spillway.

Photo 1-23. Polacca Wash Dam No. 2, looking northeast along crest of dam. Sediment has almost completely filled reservoir area, right of photo.

Photo 1-24. Polacca Wash Dam No. 2. View showing vegetative growth on upstream floodplain.

Photo 1-25. Polacca Wash Dam No. 1. View is looking upstream showing failed dam. The people and vehicle are on the crest of the dam.

GRADE STABILIZATION STRUCTURES

These structures control the channel grade and prevent the formation or advancement of gullies. The structure is normally a drop spillway, chute spillway or box inlet drop spillway. The weir crest is often placed higher than the streambed to induce sediment deposition and drown out headcuts. In this sense, the structure acts as a barrier dam; however, floodwater and sediment storage are usually not a part of the design. All of the runoff and sediment that reaches the structure is passed over the weir after sediment accumulates to the level of the weir crest.

Grade stabilization structures can be constructed from a variety of materials including rock, gabions, steel, concrete, and masonry. Their technical feasibility has been well demonstrated throughout the Southwest. The main hindrance to widespread use is the high cost of construction.

Examples of the value of large grade stabilization structures are the two grouted rock drop structures installed on Figueredo Wash at Mexican Springs, New Mexico, about 20 miles north of Gallup, New Mexico. The site is within the San Juan River Basin; however, it is only a few miles east of the boundary of the Little Colorado River Basin. Conditions are similar to those within much of the Basin. In 1936, the CCC constructed these structures to direct flows onto range test plots as part of the Mexican Springs Experimental Station (Hubbell and Gardner, 1950). Both structures are still intact (see Photos 1-26 and 1-27). They have been very successful in stabilizing the channel and promoting vegetative growth (see Photos 1-28 and 1-29).

Photo 1-26. Figueredo Wash (San Juan River Basin). Grouted rock drop structure constructed by CCC. View is looking upstream.

Photo 1-27. Figueredo Wash (San Juan River Basin). Grouted rock drop structure. View is looking upstream. This structure is about one mile upstream from the structure in Photo 1-26.

Photo 1-28. Figueredo Wash. View is looking upstream showing sediment deposits and vegetative growth resulting from drop structure. This structure is the same as the one shown in Photo 1-27.

Photo 1-29. Figueredo Wash showing trenched alluvial valley. This reach is about two miles downstream of the drop structure shown in Photo 1-26.

STREAMBANK PROTECTION

Structural streambank controls are devices used to prevent bank erosion and control channel meander. They slow the velocity of water adjacent to the bank, prevent scour and induce sediment deposition. These structures are constructed of a variety of materials, including rock, concrete, steel rail, etc. There are several examples where structural streambank controls have been applied in the Basin. Farmers along the Little Colorado River at Springerville and Nutrioso Creek near Nutrioso have installed loose rock structures. The Corps of Engineers has installed steel jacks to protect a flood control levee at Holbrook. Indians on the Navajo Reservation have used simple timber jacks made from juniper for many years along Ganado Wash and elsewhere. Similar examples could be cited to show that streambank protection is an effective way to control bank erosion. Their main drawback is the high cost in relation to the value of property being protected. Costs can range from $5 per foot for simple timber jacks to as high as $600 per foot for extensive treatment requiring derrick stone or driven rail on major streams. This high cost means that streambank protection is usually only justifiable to protect valued properties.

King (1970) believes that streambank protection measures are often dysfunctional. Channel widening through bank erosion and channel meander is nature's way of ultimately healing gullies.

CONCLUSION AND RECOMMENDATIONS

This section discusses the conclusions reached and recommendations for construction of structural erosion control practices in the Basin. The recommendations include suggested changes in policy as well as changes in design and construction.

Restoration of Trenched Valleys

There are hundreds of miles of trenched valleys in the Basin. Examples are the Puerco River (164 miles), Polacca Wash (96 miles), Jeddito Wash (60 miles), Oraibi Wash (92 miles), etc. The lengths given are only for the main stem; gullied tributaries are not included.

An admirable objective in any broad erosion control program for the Basin would be to restore the trenched valleys to their pre-trenched condition as existed in the early 1800's. Unfortunately, such a program is not feasible. The only practical method of restoring a large arroyo to its pre-trenched condition is to construct a large barrier structure (detention dam, retention dam or grade stabilization structure) across the channel. Upstream land treatment cannot restore a severely trenched valley in arid and semiarid climates. In fact, an upstream land treatment program, regardless of its on-site benefits, is dysfunctional toward the restoration of a trenched valley. Arroyos can only be filled by sedimentation. Sediment captured in the upper watersheds would not be available to fill in downstream channels. This certainly does not call for the abandonment of upstream treatment; however, its limitations toward restoring trenched valleys should be recognized.

King (1970) states, "It is a sobering fact that no gullied stream valley in the Western United States has ever been restored by man to its pre-trenched condition." This is probably correct. The technical means (i.e., barrier dams) are available to restore the trenched valleys in the Basin but a broad program of restoration would require hundreds of millions of dollars in expenditures. The main arroyos in the Basin are either stable or aggrading. Although bank erosion is occurring, the main channels are not deepening. Gully advancement is by headcutting on the tributaries. Resources should be spent on stabilizing active headcuts and improving vegetative cover. USDA cannot favorably recommend any broad program to restore the trenched valleys in the Basin.

The Construction of Large "Water Spreaders"

Resources have been spent in the past on barrier dams, referred to locally as "water spreaders" across the main arroyos in the Basin. Examples include structures on Polacca Wash, Wepo Wash, Slick Rock Wash and Steamboat Wash. These are large embankments. Because of their size and storage capacity, they should be classified as retention or detention dams instead of water spreaders. These structures were constructed for the purposes of utilizing captured floodwaters for growing "Indian corn" or spreading floodwater over alluvial terraces for increased forage production. Many of these structures have not met their main objectives; although they have provided other benefits. They have induced sedimentation, restored the valley floor, raised the water table, and provided wildlife habitat by inducing vegetative growth. Unfortunately, several have failed and others are in danger of failing, primarily because of their inability to handle high sediment loads and breaching through erosive earth spillways.

The U.S. Bureau of Indian Affairs has recognized some of the shortcomings of constructing large water spreaders. The current plans of the Hopi Agency call for the investigation of small trial irrigation systems and other possible sources of water.

Stabilization of Active Headcuts

Headcuts can be stabilized by either cutting off the water that reaches the site, installing a grade stabilization structure, or constructing a barrier dam to drown out the face of the headcut and induce sedimentation.

An active headcut where immediate treatment is needed is on Tze Chizzi Wash within the Navajo-Hopi Joint Use Area about one-half mile northeast of Low Mountain Trading Post (see Photos 1-30 and 1-31). A grade stabilization structure at this site is needed. They are also needed elsewhere in the Basin.

Retention/Detention Dams

The USDA studied two sites within the Basin that offer the potential for the construction of new large sediment detention reservoirs: Aguirre Wash and Coyote Creek. Both sites are located south of St. Johns, Apache County, Arizona. They are described in detail in Appendix II, Section 4, DEVELOPMENT OF SURFACE WATER RESOURCES.

Photo 1-30. Active Headcut, Tze Chizzi Wash, Low Mountain Trading Post, Navajo County, Arizona

Photo 1-31. Active Headcut, Tze Chizzi Wash, Low Mountain Trading Post, Navajo County, Arizona.

Streambank Protection

Structural streambank protection measures should only be installed to protect valued properties. Although bank erosion is occurring within the Basin on the Little Colorado River near Springerville, Nutrioso Creek at Nutrioso, the Little Colorado River at Joseph City, the Puerco River at Chamber and Sanders and elsewhere; any needed protection can be met by on-going programs and USDA does not recommend any accelerated streambank protection measures as part of this study.

Repair and Rehabilitation of Existing Structures

A major priority in the Basin should be given to the repair of many failed structures and also to insuring that other functioning structures continue to maintain structural integrity.

The USDA recommends that the existing emergency spillway system for Polacca Wash Dam No. 2 be modified. The existing spillway (see Photo 1-22) has numerous dikes constructed across it that divide the spillway into "bays." It is doubtful if this system can withstand a major flood. The spillway is already starting to fail from gully advancement. A concrete chute spillway at this site is needed. This spillway would outlet into the channel downstream of the dam.

The USDA located several failed structures during the course of this study that offer excellent potential for repair. Examples include Youngs Canyon Tank (see Site Report in Appendix II, Section 4, DEVELOPMENT OF SURFACE WATER RESOURCES) the Steamboat Wash "water spreaders" (see Photo 1-32) and the concrete diversion dam on Jadito (Jeddito) Wash for the Jeddito Project. There undoubtedly are many other structures located in remote areas not visited by USDA that are amenable to similar treatment. USDA's recommendations are:

1. Inventory failed structures to determine the extent of repairs needed. If repair is practical and feasible, develop designs and costs. Particular attention should be addressed to those sites where a stable rock spillway could be provided at minimal expense (see Photo 1-32).

2. Inventory embankment structures that need upgrading to present standards to prevent possible failure. There are many large embankments in the Basin where failure would be damaging and expensive to repair, undoing years of effort. An example is Zion Dam.

3. Agencies and individuals involved in erosion control work could seek changes in existing federal cost-share assistance programs to provide for repair or upgrading of structures. Under current policy, repair work is not on an equal footing with new construction.

In summary, the first priority of any structural program to control erosion in the Basin should be to protect and maintain existing structures to insure their integrity.

Photo 1-32. Failed water spreader dike, Steamboat Wash, Navajo Indian Reservation, Apache Canyon, Arizona. This structure could be repaired and a rock spillway provided at minimal expense.

Site Selection and Design

The number of failures of earthen embankments within the Basin, particularly on the Indian lands north of the Little Colorado River is alarming. The agencies involved in construction within the Basin generally have adequate design standards and specifications for the design and construction of embankments. However, many failures are directly attributed to loss of capacity from siltation and subsequent breaching through an earth spillway. More design emphasis should be given to these factors. USDA has the following recommendations to lessen the danger of failure for embankments constructed in the future:

1. Design for sediment - All agencies, including USDA, that are involved in the design and construction of storage, or diversion structures within the Basin, should elevate the computation of anticipated sediment accumulation to the same degree of status that other design parameters, including flood hydrology and foundations, have in the design. This is not a problem in project-type action; however, it is in non-project type construction that constitutes the bulk of embankment work in the Basin (see Photo 1-33).

2. Site selection - An overriding consideration in the location of embankment structures should be to have a nonerosive spillway wherever possible. This is particularly true in high sediment yield areas.

Photo 1-33. Failed water spreader, Muddy Wash, Mexican Springs, New Mexico (San Juan Basin). View is looking down the crest of the dike, showing breached section and storage area completely filled with sediment.

Photos 1-34 and 1-35 show the failure of a debris basin from breaching through a poorly located structure. In contrast, Photos 1-36 and 1-37 show the positive benefits from proper site selection.

RESEARCH NEEDS

A channel grade stabilization structure is an effective way to stabilize active headcuts and control erosion. The main drawback of these structures is the high cost of installation, particularly in areas of fine-grained soil that are most subject to erosion. Suitable rock is seldom available within economical haul distances. Gabions and reinforced concrete drop structures are very expensive; requiring extensive foundation preparation to guarantee structural integrity.

A primary need in the Basin, and elsewhere in the arid and semiarid Southwest, is for a relatively inexpensive grade control structure. There are two types of structures that offer promise; a concrete baffled apron spillway and steel sheet piling.

The Bureau of Reclamation (1964 and 1979) has conducted extensive research and developed hydraulic and structural design criteria for concrete baffled apron spillways. These structures have been used successfully at many locations primarily as emergency spillways for large floodwater retarding

Photo 1-34. Breached emergency spillway of a debris basin, Navajo Indian Reservation, Apache County, Arizona. The dam is shown in center of photo. A stable spillway could have been provided at this site with little extra expense by placing the spillway through rock on the hill.

Photo 1-35. Breached emergency spillway of debris basin shown in Photo 1-34. View is looking upstream. People in the photo are standing on original spillway crest.

Photo 1-36. Debris basin, Navajo Indian Reservation, Apache County, Arizona. View shows sediment accumulations. The spillway is in stable rock.

Photo 1-37. Gully downstream of debris basin shown in Photo 1-36. This scene (downstream) is in vivid contrast with that shown in Photo 1-36 (upstream).

structures or grade control structures in water conveyance canals. Applications to date have required detailed site specific studies. Agencies involved in erosion control work should consider the use of this type of grade control structure in their erosion control programs and develop the design tools necessary for widespread applications at the field level. This effort should include simplified methods to compute the maximum scour to be anticipated for various soil and flow conditions.

Steel sheet piling drop structures have been installed at two locations in New Mexico; the Alamogordo Creek Experimental Watershed southeast of Albuquerque and the Ladrone Peak area about 20 miles northwest of Socorro where climatic and soil condition are very similar to those encountered in many eroded areas of the Little Colorado River Basin. The degree of success has been variable, ranging from complete failure to fair success.

The Alamogordo Creek structure is a large steel drop constructed by the Science and Education Administration, formerly the USDA-Agricultural Research Service, in 1970 to control a rapidly advancing headcut. (USDA-ARS 1970, 1972.) The structure was tested during a storm in July 1972, suffered some damage, but performed well and is still functional.

The U.S. Bureau of Land Management installed several steel sheet piling drop structures near Socorro in the 1960's. Several structures failed. King (1970) examined several of the structures in 1966 and states "...initial results would seem to discourage the use of steel piling to form drop structures. The writer, however, came away convinced that the deficiencies... were wholly of a design and constructional nature and in no way discredited the basic idea of using steel sheet piling as a practical and economical form of streambed control." USDA (1979) examined six of these same structures in the fall of 1978 and agree with King's assessments (see Photos 1-38 and 1-39).

The U.S. Bureau of Land Management was quite active in the 1960's in the construction of sheet metal piling structures. This effort may have in part been due to individual efforts and philosophies of engineers and conservationists employed at that time. BLM use of steel has slackened considerably since 1967, possibly being discouraged by failures or from changes in program priority.

King states "the use of interlocking sheet steel piling to build checkdams and drop structures may well prove to be the most important contribution made in several decades to structural aspects of erosion control in areas underlain by finegrained sediment." More research and actual field installation of steel structures is highly recommended.

Another area of needed research is the subject of salinity. This is a complex issue. Research data is needed on the processes of salt pickup in streams and channels and through reservoirs, and the effects of watershed treatments on salinity loads in receiving waters.

Photo 1-38. Steel drop structure (Elizabeth No. 1) constructed by Bureau of Land Management near Socorro, New Mexico. (Rio Grande River drainage)

Photo 1-39. Steel drop structure (Elizabeth No. 2) constructed by Bureau of Land Management near Socorro, New Mexico. (Rio Grande River drainage)

USDA AND OTHER PROGRAMS

Installation of either of the alternative plans would require significant input from several agencies, groups, organizations and other units of government. Coordinated interagency planning is essential. The agencies, groups, etc. that have been identified as having a significant involvement are discussed below.

SOIL CONSERVATION SERVICE - USDA

The Soil Conservation Service (SCS) administers three programs that would be affected by plan implementation. The first of these is the Conservation Operations (CO) Program. This program operates under the guidance of local Natural Resource Conservation Districts in Arizona; Soil and Water Conservation Districts in New Mexico and on the Navajo and Hopi Reservations, and would provide technical assistance in the planning and application of resource management systems on rangeland. The establishment of SCS offices and districts on the reservations is currently underway. It is anticipated that five districts will be established on the Navajo Reservation and one district on the Hopi Reservation. It is expected that an additional five to six full-time conservationists would be required to provide technical assistance to these districts.

The Resource Conservation and Development Program could also be affected by plan implementation. Using this program, local sponsors could receive technical and financial assistance in the planning and installation of project measures.

The SCS also administers the Watershed Protection and Flood Prevention Act, Public Law 83-566. The only PL-566 project currently being planned within the Basin is the Cottonwood Wash Watershed in Navajo County, Arizona. Installation of either of the two alternative erosion control plans would need to be coordinated with planning and installation of the Cottonwood Wash Project.

AGRICULTURAL STABILIZATION AND CONSERVATION SERVICE (ASCS) - USDA

The ASCS administers the Agricultural Conservation Program (ACP). Through this program the ASCS supplies funds to cost-share (50 to 75 percent) in the installation of conservation practices. Most of the practices included in the alternative plans would be eligible for cost-sharing assistance under the ACP. Since either of the alternative plans would greatly accelerate the installation of conservation practices, a larger allocation of ACP cost-sharing funds to the Little Colorado River Basin area would be needed.

FARMERS HOME ADMINISTRATION - USDA

The Farmers Home Administration (FmHA) administers several loan programs, including farm ownership and operation loans, soil and water conservation loans, grazing association loans and resource conservation loans.

Since many of the ranchers in the Basin, particularly those on the Indian Reservations, lack the financial capability to finance their share of the needed conservation practices, the FmHA would need adequate funds to be able to provide needed financial help.

FOREST SERVICE - USDA

The Forest Service administers two types of programs which can be used to reduce erosion and sedimentation in the Basin:

1. Management of National Forest Lands. Long-term objectives include: repairing degraded watershed areas and achieving soil stability through the control of surface runoff and erosion. The Coconino and Apache-Sitgreaves National Forests will complete forest management plans by 1983 which will identify opportunities to reduce erosion and sediment problems. In some areas a watershed condition survey will be conducted.

Water improvement prescriptions are prepared to correct unsatisfactory erosion and sedimentation conditions. These could include: channel stabilization, sediment retention structures, stabilization of soil by mechanical means, reducing soil compaction forces, such as livestock trampling through management and eliminating movement of machines and vehicles during critical periods, modifying timber cutting and livestock grazing practices to increase soil infiltration rates and available water capacity, managing vehicle travel on nonsurfaced roads and in offroad use areas to prevent soil conditions which result in erosion.

Funding National Forest Soil and Watershed Restoration Projects is obtained through the Forest Service's annual budget process. This includes work which may be done as part of a PL-566 small watershed project or PL-534 flood prevention project.

2. The Arizona State Land Department, Division of Forestry, can provide technical planning assistance to landowners for reducing erosion and sedimentation on forested private lands. This program is cooperatively funded through the Forest Service. Prescriptions generally include modification of silviculture practices aimed at improving watershed conditions. Forest Service or state funds are not available for implementation of the recommended silviculture practices or for installing structures. Forest landowners may qualify for ASCS cost-share funds or FmHA loans to help pay for this work.

The Forest Service participates in the Small Watershed Program and the Flood Prevention Program, having responsibility for the forested acres. The SCS is the lead agency. The Forest Service provides technical assistance to landowners either directly or through state forestry agencies. Cost-sharing for implementation of tree planting, critical area stabilization and other soil stabilizing measures is available to landowners through the ongoing ACP.

The Forest Service participates in a similar manner in the Special Water Quality Agricultural Conservation Programs. Again, only technical assistance is provided to landowners. Cost-sharing for implementation of soil stabilization measures on forest lands must come from other programs.

SCIENCE AND EDUCATION ADMINISTRATION - AGRICULTURE RESEARCH - USDA

The Science and Education Administration-Agriculture Research Service, individually or in cooperation with experiment stations, conducts research in soil, plant and water technology. Research is essential to provide direction for installation of a complete land and water resource program which will assure maximized benefits to individuals, the communities, the Basin and the Nation. Development of new or improved technology and increased application of the present technology are important opportunities. One opportunity is to perfect methods to reduce erosion and sediment yields, improve infiltration and establish protective vegetative cover which is suitable for domestic livestock and wildlife use on disturbed areas. Continued research in "water harvesting" techniques will assist in range management through a better distribution of livestock water supplies.

BUREAU OF LAND MANAGEMENT - USDI

The Bureau of Land Management (BLM) is entrusted with the stewardship of the public lands. It is committed to the principle that these lands shall be devoted to the best combination of uses in service of the Nation and the people, now and in the future. It has exclusive jurisdiction over about 4.4 percent of the Basin area. The resource protection, management and development activities of the BLM are conducted under a multiple use philosophy which attempts to maximize the total public and private benefits obtainable from the available financial and land resources.

The BLM carries out a coordinated program for the conservation and development of watersheds in order to preserve and protect the soil and water resources. This program is a combination of land treatment and structural practices having a planned pattern in support of multiple use management. It is designed to regulate surface water runoff to control erosion and to stabilize the soil resources.

Through the granting of grazing license, permits and leases, the BLM administers grazing activities to protect the productivity of the lands and to permit the highest use of forage. The BLM also carries out programs for the rehabilitation of deteriorated rangelands to obtain continuous production at the highest possible level.

The 1934 Taylor Grazing Act expresses concern for water and the need for range management. As stated in its preamble, this is "an act to stop injury to the public grazing lands by preventing overgrazing and soil deterioration; to provide for their orderly use, improvement and development; to stabilize the livestock industry dependent upon the public range; and for other purposes." Section 4 of that Act provides in part, "fences, wells, reservoirs and other improvements necessary to the care and management of the permitted livestock may be constructed on the public lands within such grazing districts under permit issued by the authority of the Secretary of the Interior, or under such cooperative arrangements as the Secretary may approve."

The above policy was further confirmed and expanded with the passage of the Federal Land Policy and Management Act of 1976. This Act calls for comprehensive land use planning. It provides broad management authority under principles of multiple use and sustained yield in accordance with land use plans. It provides a formula for the distribution of funds collected from grazing fees. Fifty percent of all money collected will be used for range improvement programs.

Congress also provides additional funds to the BLM to improve the range condition of public rangelands, through the passage of the Public Rangelands Improvement Act of 1978. This Act authorized the appropriation of ..."$15,000,000 annually in fiscal years 1980 through 1982; for fiscal years 1983 through 1986 an amount no less than the amount authorized for 1982; and for fiscal years 1987 through 1999 an amount not less than $5,000,000 annually more than the amount authorized for fiscal year 1986. Such funds should be in addition to any range, wildlife and soil and water management moneys which have been requested by the Secretary of Interior under the provisions of Section 318 of the Federal Land Policy and Management Act, and in addition to the moneys which are available for range improvements under Section 401 of the Federal Land Policy and Management Act."

BUREAU OF INDIAN AFFAIRS - USDI

Since nearly 48 percent of the Little Colorado River Basin is Indian lands, the Bureau of Indian Affairs (BIA), U.S. Department of the Interior, plays a significant role in managing the resources of the study area. The BIA acts as a trustee for Indian lands and moneys and assists the Indians in making the most effective use of their resources.

The policies under which the BIA operates with respect to Indian land resources include the retention of ownership by Indians and resource management for sustained-yield benefits. This entails the primary duty of providing technical services in matters of resource management. These services include programs for protection of land against erosion and soil deterioration, the restoration of eroded and depleted areas and the improvement of production on rangeland.

In addition to technical services, funds are sometimes provided on a limited basis for the installation of physical structures. Funds for special projects are obtained from Congress and administered by the BIA.

AGRICULTURE EXTENSION SERVICE

Educational work of soil and water conservation is carried on through the Extension Service. In order for the planned alternatives to be effectively applied, the farmers and ranchers must be informed of the potential benefits and methods of application. They should be informed of the programs and services offered by the various federal and state agencies, and of new technology available for improving grass production and controlling erosion. Each of these is a function of the Extension Service.

NATURAL RESOURCE CONSERVATION DISTRICTS (NRCD'S) AND SOIL AND WATER CONSERVATION DISTRICTS (SWCD'S)

NRCD's and SWCD's are entities of state government organized by local referendum under provisions of state law and laws of the Tribal Codes for the reservations. Both types of districts are directed by local elected boards of supervisors. They provide local programs of resource planning, development, and utilization, and furnish a means for individual citizens and organized groups to participate in the planning and installation of soil and water conservation practices needed to protect and improve the land, water and related resources.

Their programs are largely carried out with technical assistance furnished by the SCS under memoranda of understanding. Other federal and state agencies participate in carrying out district objectives.

Except for the Indian reservations, the total Basin is covered by districts, either NRCD's or SWCD's. There are three NRCD's in the off-reservation Arizona portion of the Basin. These are the Apache, Coconino and Navajo County NRCD's. There are parts of four SWCD's in New Mexico. These include Quemado, McKinley, Lava and Salado SWCD's.

Present plans call for the forming of five SWCD's on the Navajo and one on the Hopi Reservation. The Little Colorado River SWCD has been organized on the Navajo Reservation. This is the first conservation district in the United States to be formed under Tribal Law.

The conservation district is organized under the provisions of Title III of the Navajo Tribal Code enacted by the Navajo Tribal Council on February 7, 1980.

The district is located primarily in Coconino County with a small portion of the southeast corner extending into Navajo County.

The district contains the seven Navajo Chapters of Bodaway Gap, Cameron, Coalmine Mesa, Tuba City, Bird Springs, Leupp and Tolani Lake. The total land area is about 2,166,673 acres.

The Memorandum of Understanding between the Secretary of Agriculture and the Conservation District was signed April 10, 1981.

REFERENCES

1. Antevs, E., Arroyo-Cutting and Filling. Journal, Geology, Vol. 60, 1952.

2. Bailey, Reid W., Epicycles of Erosion in the Valleys of the Colorado Plateau Province: Journal of Geology, XLIII, 1935.

3. Bennett, Hugh H., Soil Conservation: New York and London, McGraw-Hill, 1939.

4. Bryan, Kirk, Date of Channel Trenching (Arroyo Cutting) in the Arid Southwest: Science, LXII, 1925.

5. Cambell, Ian A., Climatic Variation and Overgrazing: An Assessment of Their Relative Effects on the Present Landscape of the Shonto Plateau, Arizona, 1969: University of Alberta, Edmonton, Alberta, Canada. Abstracts, Arid Lands in a Changing World, 3-13 June 1969. Conference sponsored by the American Association for the Advancement of Science, U of A, Tucson, Arizona.

6. Colton, Harold S., Some Notes on the Original Condition of the Little Colorado River; A Side Light on the Problems of Erosion: Museum Notes, Museum of Northern Arizona, December 1937.

7. Cooley, M.E., J.W. Harshbarger, J.P. Akers and W.F. Hardt. 1969 - Regional Hydrogeology of the Navajo and Hopi Indian Reservations, Arizona, New Mexico and Utah. With a Section on Vegetation by D.N. Hicks. U.S. Geological Survey Professional Paper 521-A.

8. Cottam, W.P. and Stewart, George, Plant Succession as a Result of Grazing and of Meadow Desiccation by Erosion Since Settlement in 1862; Journal of Forestry, XXXVIII, 1940.

9. Dellenbough, F.S., Cross Cutting and Retrograding of Streambeds: Science XXXV, 1922.

10. Gifford, G.F. and Hawkins, R.H., Grazing Systems and Watershed Management; A Look at the Record: Journal of Soil and Water Conservation 31, 1976.

11. Graham County Board of Supervisors, Photographs and Supporting Statement by the Board and the Virden-Duncan and Gila Valley Irrigation Districts before Major Theodore Wyman, U.S. Army Corp of Engineers, 1935.

12. Gregory, H.E., Geology and Geography of the Zion Park Region, Utah and Arizona: U.S. Geological Survey Professional Paper 220, 1950.

13. Hadley, R.F., Characteristics of Sediment Deposits Above Channel Structures in Polacca Wash, Arizona; U.S. Department of Agriculture, Agricultural Research Service, Federal Interagency Sedimentation Conference Proc., Misc. Pub. No. 970, 1963.

14. Harnes, C.F., D.M. Sickle and H.V. Peterson, 1952. Sedimentation Rates in Small Reservoirs in the Little Colorado River Basin. Geological Survey Water - Supply Paper 1110-D. U.S. Geological Survey.

15. Hastings, James R., Vegetation Change and Arroyo Cutting in Southeastern Arizona During the Past Century - An Historical Review: Arid Lands Colloquia, U of A, Tucson, Arizona, 1958-1959.

16. Hastings, James R., Vegetation Changes and Arroyo Cutting in Southeastern Arizona; Journal of the American Academy of Science, I 60-67, 1959.

17. Hastings, James R. and Turner, Raymond, The Changing Mile: U of A Press, Tucson, Arizona, 1965.

18. Howell, J.V., Glossary of Geology and Related Sciences, American Geology Institute, 1957.

19. Hubbell, D.S. and Garner, J.L., Effect of Diverting Sediment-Laden Runoff from Arroyos to Range and Crop Lands. U.S. Department of Agriculture Technical Bulletin 1012, 1950.

20. Judson, Sheldon, Arroyo: Scientific American CLXXXVII, 1952 <u>in</u> The Changing Mile, Hastings and Turner, U of A Press, Tucson, Arizona, 1965.

21. King, N.J., Erosion Control on Arid and Semiarid Rangeland: U.S. Geological Survey, Denver, Colorado, Unpublished Report, undated, assumed 1970.

22. Knechtel, Maxwell M., Geology and Ground Water Resources of the Valley of the Gila River and San Simon Creek, Graham County, Arizona: U.S. Geological Survey, Water Supply Paper 796-F, 1938.

23. Leopold, Luna B. and Miller, John P., A Postglacial Chronology for Some Alluvial Valleys in Wyoming: U.S. Geological Survey, Water Supply Paper 1261, 1954.

24. Leopold, Luna B. and Snyder, C.T., Alluvial Fills Near Gallup, New Mexico: U.S. Geological Survey, Water Supply Paper 1110-A, 1951.

25. Lowdermilk, W.C., Conquest of the Land Through Seven Thousand Years: USDA Bulletin No. 99, 1953.

26. Olmstead, F.H., Gila River Flood Control, 65th Congress, 3rd Session, Senate Document 436, 1919.

27. Peterson, H.V., The Problems of Gullying in Western Valleys: Applied Sedimentation, John Wiley and Sons, New York, N.Y., 1950.

28. Schulman, Edmund, Tree-Ring Hydrology in Southern California, Laboratory of Tree-Ring Research Bulletin No. 4, U of A, Tucson, Arizona, 1947.

29. Soil Conservation Society of America, Resource Conservation Glossary, Journal of Soil and Water Conservation 25 (1, supplement): 1-52, 1970.

30. Stockton, Charles W. and Gordon C. Jacoby, Jr., Long-Term Surface-Water Supply and Streamflow Trends in the Upper Colorado River Basin Based on Tree-Ring Analysis. Lake Powell Research Project Bulletin 18, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, 1976.

31. Thornthwaite, C.W., Sharp, C.F., and Dosch, E.F., Climate and Accelerated Erosion in the Arid and Semiarid Southwest with Special Reference to the Polacca Wash Drainage Basin, Arizona: USDA Bulletin 808, 1942.

32. U.S. Bureau of Land Management, The Effects of Surface Disturbance on the Salinity of Public Lands in the Upper Colorado River Basin, Denver, Colorado, 1978.

33. U.S. Bureau of Reclamation, Report on Sediment Deposition Above Zion Dam, Little Colorado River Basin, Arizona, 1955.

34. U.S. Bureau of Reclamation, Hydraulic Design of Stilling Basins and Energy Dissipators, Water Resource Technical Publication Engineering Memorandum No. 25, GPO, Washington, DC, 1964.

35. U.S. Bureau of Reclamation, T or C Baffled Apron Spillway, Technical Report No. GR-79-2, prepared for the U.S. Soil Conservation Service, Albuquerque, New Mexico, USBR, Engineering and Research Center, Denver, Colorado, April 1979.

36. USDA, Agricultural Research Service, Annual Progress Report, 1970, Southwest Watershed Research Center, Tucson, Arizona.

37. USDA, Agricultural Research Service, Annual Progress Report, 1972, Southwest Watershed Research Center, Tucson, Arizona.

38. USDA, Soil Conservation Service, Field Evaluation of Sheet Metal Piling Drop Structures near Socorro, New Mexico, unpublished field report by John E. Weaver, Engineer, USDA-SCS, Phoenix, Arizona, February 1979.

39. USDA, Soil Conservation Service, Engineering Report on Hickman Wash Flood Problem, Fort Defiance, Arizona, Phoenix, February 1979.

40. U.S. Department of the Interior, Geological Survey, Water Resources Data for Arizona, Water Year 1978, Report AZ-78-1.

41. U.S. Department of the Interior, Bureau of Reclamation and U.S. Department of Agriculture, Soil Conservation Service, 1977. Final Environmental Statement, Colorado River Water Quality Improvement Program, Volume I.

42. U.S. Forest Service, Wildland Planning Glossary, Pacific Southwest Forest and Range Experiment Station, General Technical Report, PSW-13, 1976.

43. Weiler, Fred J., Rehabilitation of the San Simon Watershed: Abstracts, Arid Lands in a Changing World Conference, 3-13 June 1969. Sponsored by the American Association for the Advancement of Science, U of A, Tucson, Arizona.

44. Wooley, R.R., Cloudburst Floods in Utah 1850-1928: U.S. Geological Survey, Water Supply Paper 994, 1946.

SECTION 2

FLOODING

SECTION 2

FLOODING

TABLE OF CONTENTS

SECTION 2

FLOODING

INTRODUCTION

The purpose of this study was to determine the potential for USDA project actions that could be taken to solve significant flood problems in the Basin. Opportunities for project action under the Watershed Protection and Flood Prevention Act (Public Law 566) and Resource Conservation and Development (RC&D) measures were investigated. These investigations were limited to determining the need for structural measures. Flooding along the main stem of the Little Colorado River and other areas that have a drainage area in excess of 250,000 acres were not studied because drainage areas larger than 250,000 acres exceed USDA authority, but studies by other agencies on these streams are included in this report.

FLOOD PREVENTION MEASURES AND STUDIES

GENERAL

Arizona

The U.S. Army Corps of Engineers has constructed two flood control measures within the Basin; the Holbrook levee (1948) on the Little Colorado River at Holbrook, and Ruby Wash Diversion (1970) at Winslow (3).* A second measure at Winslow, the Ice House Wash Channel Improvement, is authorized and federally funded. However, the local administration found a more desirable alternative solution which was designed and installed by the Arizona Department of Transportation in conjunction with the drainage work for Interstate Highway 40.

The Corps has completed Flood Plain Information Reports on Rio de Flag Wash and Sinclair Wash at Flagstaff, and on the Little Colorado River at Winslow.

The Corps has performed emergency repair work under Public Law 84-99 on the Little Colorado River at Holbrook (1971, 1972), the Little Colorado River at Winslow (1971, 1972), and Daggs Dam on Silver Creek (1973).

The Corps recently completed an investigation on the Little Colorado River at Holbrook. This study recommends modifying the existing Holbrook levee project. The protection afforded by the levee has been greatly reduced due to siltation in the Little Colorado River channel.

The Corps has an authorized but unfunded study of flood problems on the Navajo Indian Reservation. This study, authorized by Section 176 of the 1976 Water Resources Development Act (Public Law 94-587), is to provide information on flood control and related problems. The study will begin when funds are made available.

*Numbers refer to listed references in back of this section of the appendix.

The Arizona Department of Water Resources (ADWR), under the authorities of the Arizona Alternative Flood Control Assistance Program, completed an investigation and have prepared preliminary designs for a levee system on the Little Colorado River to provide flood protection for Winslow. The project is ready to go into final design as of August 1981.

ADWR has also completed a reconnaissance level flood control study on the repair of Lone Pine Dam, which is on Show Low Creek in southern Navajo County southwest of Taylor.

Morrison Maierle, Inc. of Helena, Montana, a consulting engineer firm under contract with the Bureau of Indian Affairs, Navajo Area Office, has completed a study (June 1977) that determines flood prone areas on the Navajo Reservation. (2)

The Bureau of Indian Affairs and the Navajo and Hopi Indian Tribes have constructed a multitude of structures on the reservations as part of their soil and water conservation programs. Many of these structures provide some degree of flood control by retaining the runoff from the smaller storms. These structures are the most effective immediately following construction; their capacity being reduced over time due to siltation. A large structure on the Navajo Reservation is the Canyon Diablo Dam and reservoir, constructed primarily as a recreation impoundment on Canyon Diablo Wash near Leupp. Another relatively large project is the Polacca Wash water spreader/grade stabilization structure complex on the Hopi Reservation.

New Mexico

The U.S. Army Corps of Engineers first addressed the Gallup flood problem in a study and report entitled "Report on Survey - Flood Control - Little Colorado River and Its Tributaries Upstream From the Boundary of the Navajo Indian Reservation in Arizona," dated December 5, 1940. This report considered the feasibility of providing protection from floods on the Puerco River and the Little Puerco Wash, but found that no improvements for flood control could be economically justified. These findings were confirmed in reports prepared in 1955 and 1966.

Further involvement by the Corps resulted in flood-damage reports on the floods of July 1972 and September 1975. In April 1974, a flood plain information report presented flood hazard information for the reach of the Puerco River within and near the City of Gallup.

Recently, the Corps prepared another report in response to a resolution dated October 12, 1972, adopted by the Committee on Public Works of the House of Representatives. The resolution requested the Board of Engineers for Rivers and Harbors to review a 1968 report by the Chief of Engineers on the Little Colorado River, Arizona and New Mexico "...with a view to determining whether improvements at and in the vicinity of Gallup, New Mexico, for flood control, are advisable at this time." (4)

The New Mexico State High Department has completed some channel work along the Puerco River in conjunction with the construction of Interstate 40 through Gallup.

Several reports have been prepared regarding the flooding potential to the Pueblo of Zuni, New Mexico. The reports are as follows:

In 1968, the Bureau of Indian Affairs requested the Bureau of Reclamation to examine the structural condition of eight dams on the Zuni Indian Reservation. As a result of the examination, a report entitled "Examination of Dams and Appurtenant Facilities for Bureau of Indian Affairs, Zuni Indian Reservation, New Mexico" was published. It concluded that all of the dams would perform safely provided that minimum freeboards were maintained at all times; that adequate maintenance and surveillance programs were established; and that certain repair work was accomplished. A companion report, "Flood Study Report, Black Rock Dam, Zuni Indian Reservation, New Mexico," was also published. This report disclosed that under maximum probable flood conditions flows could not be safely passed through existing spillways. It concluded that a potentially serious safety hazard existed at all of the eight dams examined.

As a result of the 1968 studies, the Bureau of Indian Affairs contracted with the Bureau of Reclamation for the primary purpose of preparing designs and cost estimates to correct specific structural deficiencies at the eight examined dams and to provide adequate flood control facilities for safety purposes along the Zuni River. (7)

In 1972, the Corps of Engineers, Los Angeles District, prepared a special flood hazard report for the Zuni Pueblo. The purpose of this report was to present information on the flood hazard along the Zuni River. A 2¼ mile reach of the Zuni River was studied. The Governor of the Pueblo of Zuni requested this study under continuing authority provided to the Corps of Engineers by Section 206 of the 1960 Flood Control Act (Public Law 86-645), as amended.

In 1974 a private engineering firm, Bohannan, Westman, Huston and Associates, Inc., from Albuquerque, New Mexico, prepared a report for the Pueblo of Zuni. The scope of work was to determine suitable cross sections to safely carry flows from a 100-year frequency storm through the study area. (1)

The study area extended approximately nine miles along the Zuni River, starting at the Black Rock Dam spillway and proceeding downstream. Flood flows were calculated based on the existence of three dams (Oak Wash, Yellowhouse and Galestena), which are not in place.

The Bureau of Reclamation agreed to prepare a feasibility report and environmental impact statement for the Yellowhouse Dam Project on the Zuni Indian Reservation for the Bureau of Indian Affairs (BIA) under provisions of the Memorandum of Understanding of September 16, 1977. The purpose is to obtain congressional authorization for the Yellowhouse Dam. (8)

SOIL CONSERVATION SERVICE

There are two watersheds within the Basin that have potential for development under the Watershed Protection and Flood Prevention Act (PL-566); the Pueblo Zuni Watershed and the Cottonwood Wash Watershed.

The Pueblo Zuni Watershed is located in the southwestern part of McKinley County, New Mexico. A watershed work plan was approved for operations in 1976. As of September 1981, no construction has taken place. Geology investigations have been completed and archeology investigation and preliminary design are in progress. When installed, this project will protect both urban and agricultural lands along Oak Wash on the Zuni Indian Reservation.

The Cottonwood Wash Project is located in southern Navajo County, Arizona. This project has been authorized for planning. It is expected that this will be a multi-purpose project for recreation and flood prevention. When installed, agricultural and urban lands within the Town of Snowflake will be protected from flooding.

The Soil Conservation Service's conservation operations program provides technical assistance to land owners and operators in planning and installing conservation systems. Flood control measures such as dikes and levees are frequently included in these conservation systems and can be found throughout the Basin. These measures are usually installed with cost-sharing assistance provided by the Agricultural Stabilization and Conservation Service.

OTHER FLOOD CONTROL MEASURES

There have been numerous efforts by local interests to control damaging floods within the Little Colorado River Basin. Farmers and other individual property owners have constructed diversion dikes, water spreaders, channel improvements, etc. at many locations throughout the Basin to protect their properties.

Municipalities and counties have also been active in flood control work by the construction of dikes, channel improvements and debris removal; however, most of their efforts are ineffective against large runoff events. These efforts include channel improvement and dike construction by the City of Holbrook on the Little Colorado River channel, channels and diking on Ice House Wash by the City of Winslow and the construction of an earth levee by Navajo County along the Little Colorado River north of Winslow.

There are numerous impoundments in the Basin that, by virtue of their storage, contribute to reducing downstream flood damages. These impoundments range in scale from small stockponds to large multipurpose reservoirs such as Lyman Lake. The major impoundments within the Basin are presented in Appendix II, Section 4.

The degree of flood prevention afforded by these impoundments depends upon the amount of storage that is available when a storm occurs. Very few were constructed with flood control as a primary purpose. The only dam in the Arizona portion of the Basin constructed with flood control as a purpose is the Millet Swale Dam, located east of Taylor, Arizona. This structure was constructed by the Show Low-Silver Creek Water Conservation and Power District to provide water for irrigation and to protect irrigated land and other improvements.

Other structures in Arizona that normally have some storage available to reduce flood peaks are Zion Reservoir located on the Little Colorado River

near St. Johns, Lone Pine Reservoir on Show Low Creek near Taylor and Mexican Lake which receives high stage overflow from White Mountain Lake.

In New Mexico, structures that afford some storage for flood control include Goat Ranch Nos. 1 and 2, Layton Detention No. 4, Red Hill, Knudson Lake and Marcotte Pond.

There are many closed basins within the Basin that either capture all or a major part of the runoff that enters them. These closed basins have a measurable impact on the amount of flood flows in the river basin and without them flooding would be much more severe. A map showing these areas entitled "Areas Which Contribute Little or No Streamflow to the Little Colorado River" is located in Section 1 of this appendix.

FLOOD WARNING AND FORECASTING

The National Oceanic and Atmospheric Administration (NOAA), through its National Weather Service (NWS), maintains year-round surveillance of weather conditions. NOAA estimates the intensity and duration of storm activity from radar and satellite data and issues flood warnings if conditions so warrant. Normally, these warnings are spread via local news media.

A formal warning system has been installed on the Puerco and the Little Colorado Rivers for the Cities of Holbrook and Winslow. The system includes telemetry stations installed on the Little Colorado River at Woodruff, Arizona, and on the Puerco River at Chambers, Arizona. Local efforts by Holbrook, Winslow, Navajo County and others were instrumental in establishing this warning system after the damaging Labor Day flood in 1970. A caller to the telemetry stations receives a code from which a depth of water can be determined.

This system is to be replaced in October 1981 by a statewide system being put into operation by NWS and the ADWR. A joint flood warning office, located at the NWS office in Phoenix, issues storm warnings and flood forecasts. For the Little Colorado River Basin, satellite telemetry will be transmitted from U.S. Geological Survey gaging stations on the Puerco at Chambers; Lyman Lake at Woodruff; Silver Creek near Snowflake; Chevelon Creek below Wildcat and Clear Creek below Willow Creek. These stations will provide flood forecasts for St. Johns, Holbrook and Winslow through the NWS River Forecast Center at Salt Lake City, Utah.

FLOOD INSURANCE STUDIES

The National Flood Insurance Act of 1968 (Title XIII of the Housing and Urban Development Act P.L. 90-448) recognized the necessity for flood plain management. This act makes federally subsidized insurance available to citizens in communities that adopt regulations controlling future development of their flood plains. These controls are based on evaluations of the flood hazard shown on maps produced by the Federal Insurance Administration (FIA).

The Flood Disaster Protection Act of 1973 (P.L. 93-235) significantly amended the 1968 act by making flood insurance mandatory as a condition for any

federally related financial assistance to individuals of communities wishing to acquire or refinance property or build within a flood hazard area. An amendment to this 1973 act, signed October 12, 1977, replaces Section 202(b) of the act. The amendment allows federally related banks and savings and loan institutions to lend to uninsured purchasers in flood hazard areas of non-participating (in the National Flood Insurance Program) communities. The amendment did not modify the restrictions on direct federal assistance, including VA and FHA insured mortgages, which must still have flood insurance to qualify.

Flood hazard areas are identified by two types of maps; Flood Hazard Boundary Maps (FHBM's-Emergency Program) and Flood Insurance Rate Maps (FIRM's-Regular Program). The FHBM's are temporary maps prepared from existing knowledge of flood hazard areas. The FIRM's are prepared following detailed hydrologic and engineering investigations. The target date for completion of the FIRM's nationwide is 1983.

In the Arizona portion of the Basin, all of the incorporated communities (Eagar, St. Johns, Springerville, Holbrook, Show Low, Snowflake, Taylor, Winslow and Flagstaff) are participating in the National Flood Insurance Program. The unincorporated areas of Apache, Navajo and Coconino Counties, except for the Indian Reservations, are also participating in the program.

In New Mexico, the only community that has completed a FIRM and is participating in the Regular Flood Insurance Program is the City of Gallup, McKinley County, and there are no other studies underway.

There were no areas on the Hopi, Navajo and Zuni Indian Reservations that were identified as having flood hazard problems during preparation of the FHBM's. Current contracts for completion of the FIRM's do not include reservation lands. The picture is complicated by the fact that the counties do not have the normal administrative and legal machinery for developing and enforcing flood plain regulations over reservation lands.

The present position of FIA is that they will perform flood insurance studies on a reservation upon request by the tribal council provided they adopt and use flood plain regulations and proper construction practices and building location regulations that recognize flood hazards. (9) To date, the tribes within the Basin have not requested FIA to undertake flood insurance studies.

FLOOD PROBLEMS

ARIZONA

In the latter part of 1975 and in 1976, a series of public meetings were held in the Basin to identify problems and concerns of the local people and set objectives for this study. Eight areas with flood problems were identified for the Arizona portion of the Basin. These eight areas are: (1) Round Valley, (2) Hay Hollow, (3) Holbrook, (4) Winslow, (5) St. Johns, (6) the Navajo Indian Reservation, (7) Flagstaff and (8) Snowflake-Taylor-Shumway area. Field reconnaissance investigations were made on each of these areas. The following briefly summarizes the problems identified in the reconnaissance investigation.

Round Valley

Round Valley is located in southern Apache County, Arizona, and includes the Towns of Springerville and Eagar and the agricultural areas that surround the towns. Most of the flood problems in the valley are caused by floodwaters that originate in Water Canyon. Flooding also occurs when irrigation ditches collect local runoff and overflow. Flooding occurs infrequently, but when flooding does occur, it inundates irrigated hay and pasture land, causes road and bridge damage and disrupts traffic. The developed flood plain consists of about 600 acres. Average annual damages are estimated at $15,500 (1979).

Hay Hollow

Hay Hollow is a small agricultural area located in southwest Apache County and southeast Navajo County, Arizona. Most of the flood problems are caused by floodwaters that originate in Hay Hollow Wash. Flooding occurs infrequently; but when flooding does occur, it inundates irrigated cropland, causes road and bridge damage and disrupts traffic. The developed flood plain consists of about 700 acres of irrigated cropland. Average annual damages from flooding are estimated at $18,200 (1979).

Holbrook and Winslow

Holbrook and Winslow are located in Navajo County, Arizona. Interstate Highway 40 provides access to both towns. Both are built on the alluvial flood plain of the main stem of the Little Colorado River and both are subject to major floodwater damages. The Corps of Engineers has constructed flood prevention measures for both towns. They have authorized plans to construct additional measures in Winslow and completed a plan (1980) to upgrade the protection afforded by the Holbrook levees.

The study of flood problems along the main stem of the Little Colorado River exceeds the scope of this USDA study and specific investigations on the flood problems in Winslow and Holbrook were not made.

St. Johns

St. Johns is located in southcentral Apache County, Arizona. It is a small rural town on U.S. Highway 666. This town is experiencing rapid growth as a result of construction of a large electric generating plant. The increased population is creating demands for additional residential, commercial and other development.

There are approximately 700 acres of developed flood plain of the Little Colorado River at St. Johns. This land is used primarily for irrigated hay and pasture and a small amount of urban land. Average annual damages caused by occasional flooding of the Little Colorado River amount to about $18,000 (1979). However, if urbanization is allowed to spread into the flood plain, damages in the future can be expected to increase significantly.

The Navajo Indian Reservation

The Navajo Tribe indicated that periodic flooding from Hickman and Slick Rock Washes on the east side of the Town of Ft. Defiance was a problem. USDA made a field reconnaissance investigation on the area. Occasional flooding from these washes damages about 300 acres of grassland, one house, several residential yards, a small cafe, and a service station. Average annual floodwater damages are estimated at $2,400 (1979).

Field reconnaissance investigations were also made on Leroux, Greasewood, Ganado and Upper Black Creek Watersheds. These investigations did not show significant flood problems.

Flagstaff

Flagstaff is the largest city in the Basin. It is located on Interstate Highway 40 in Coconino County. There are two areas where flooding was identified. The first of these areas is Rio de Flag Wash. The Corps of Engineers has developed a flood hazard information study for this wash. After reviewing this watershed in the field, it was decided that it did not possess significant potential for implementation under USDA authorities and was not considered further.

The second area was in the northeast section of Flagstaff. An unnamed wash that drains from San Francisco Peaks into Flagstaff appeared to have the potential to cause significant damages. Investigations revealed that the drainage area and the peak discharges are quite small and would not cause major damage. Also, the city has proposed a storm sewer system for the area which will reduce the threat of a damaging flood.

Snowflake-Taylor-Shumway

Snowflake-Taylor-Shumway area is located in southern Navajo County, Arizona, on State Highway 77. Flood problems in this area stem from Cottonwood Wash, Silver Creek and Show Low Creek.

Silver Creek is a perennial stream that originates in the area north of the Mogollon Rim in Navajo and Apache Counties. The creek flows in a northerly direction through the communities of Shumway, Taylor and Snowflake to its confluence with the Little Colorado River just south of the Town of Woodruff. There are approximately 1,400 acres of developed land subject to flooding in this watershed. Most of the flood plain is irrigated hayland, but there are also some urban damages around Taylor and Snowflake. Average annual damages are estimated at $58,100 (1979).

Cottonwood Wash also floods agricultural land and urban developments around Snowflake. This watershed is presently being planned under PL-566, the Watershed Protection and Flood Prevention Act.

NEW MEXICO

Areas identified in the New Mexico portion of the Basin as having flood problems were: (1) Gallup, (2) Pueblo of Zuni, and (3) Other.

Gallup

Gallup is located in McKinley County, New Mexico, on Interstate Highway 40. The Puerco River flows west through the city. Historical records indicate damaging floods have occurred in 1881, 1904, 1916, 1923, 1927 and 1933. Since the establishment of a U.S. Geological Survey stream gage in 1940, damaging floods have occurred in 1941, 1956, 1959, 1964, 1967, 1972 and 1975. In 1972, Gallup was declared a disaster area. Damages occurred to residential and commercial properties, streets, bridges and utilities. Average annual damages have been estimated by the U.S. Army Corps of Engineers at $311,000. (4)

Flood damages in Gallup also occur from tributaries to the Puerco River, including Coyote Canyon Wash, Little Puerco Wash, Gamerco and Black Diamond Canyon Washes, Zuni Wash, Airport Wash and Bread Springs Wash. The Corps of Engineers reports average annual damages on these tributaries total $38,700. (4)

The construction of a section of I-40 through Gallup will help reduce some of these damages by locating culverts and channels to intercept and/or convey some of the previously ponded floodwaters through the highway into the Puerco River.

Construction of the Corps of Engineers' proposed flood control project on the Puerco River through Gallup would provide a 100-year level of protection to the west part of the city. (4)

Pueblo of Zuni

Zuni Pueblo is located in the southwestern part of McKinley County, New Mexico. The Pueblo, originally built on high grounds, has expanded onto the flood plains of the Zuni River and Oak Wash. An application for assistance under the Watershed Protection and Flood Prevention Act was approved by the State of New Mexico on September 23, 1969. This application included Oak Wash, Galestena Wash and Bosson Wash. An amended application was approved by the State in August 1972, which eliminated Galestena Wash and Bosson Wash. These washes were dropped when field examinations revealed they could not be feasibly developed. About 150 acres of urban lands and 1,440 acres of agricultural lands are damaged by floodwater from Oak Wash. Average annual damages are about $185,000. (6) The plan for the Zuni Pueblo Watershed was approved for operations in June 1976. No construction has taken place as of September 1981. Geology investigations have been completed and archeology investigations and preliminary design are in progress.

Other

Minor flood problems were identified on Rio Pescado, Rio Nutria and in the Tekapo area on the Zuni Reservation. Most damages occur to agricultural lands.

Roads, bridges and culverts in the New Mexico portion of the Basin receive damage as a result of local rain storms. Damaging storms occur infrequently over the whole area.

APPROPRIATE USE OF FLOOD PLAINS

Appropriate land uses for flood plain lands include wildlife habitat, agriculture, forest products, stable ecosystems, parks or recreation areas. Most of the flood plains in the Basin are being used for grazing, with some irrigated agriculture. Consequently, most of the flood plain lands are in an appropriate land use. The only major exceptions to this are the urban areas of Holbrook and Winslow, Arizona, and Gallup, New Mexico.

The flood plains in watersheds that have drainage areas of 250,000 acres or less, the legal size limitation of USDA flood prevention projects, have the same basic land use pattern as the flood plains for the entire Basin. Some fairly significant urbanization has occurred in the flood plains of Silver Creek and Cottonwood Wash. However, the land use in most of the other flood plains is appropriate. The existing average annual flood damages, mentioned in the Flood Problems section, are comparatively small.

There are several ways that the existing appropriate use of flood plains can be maintained. In broad terms, these methods include the establishment of flood plain regulations, acquisition of flood plain lands and tax incentives for not developing the flood plain. Local units of government could employ each of these methods in varying intensities, or in combination with each other, to achieve the desired flood plain land use.

SUMMARY OF FINDINGS

The studies that were made on the areas that were identified as having flood problems did not indicate any potential for project action using USDA authorities. In all cases, the costs of significantly reducing or eliminating the flood problem exceeded the monetary benefits that would accrue.

RECOMMENDATIONS

In spite of the fact that no USDA flood prevention projects were identified, flood problems do exist. In some cases these problems can be lessened by nonstructural measures or smaller nonproject type structures. Nonstructural measures include: flood plain zoning, flood proofing to reduce damages on existing properties, flood insurance to reduce the monetary cost of flooding to individuals, relocation of urban properties out of the flood plain, tax incentives for not developing flood plains, flood forecasting, warning systems, emergency protection, post-flood recovery assistance and adopting strict development regulations and building codes.

Broad needs for nonstructural measures were identified in this study. However, the specific amounts, types, costs or locations of the needed measures were not determined. In general, flood plains along Silver Creek, the Little Colorado River and Water Canyon, Arizona, and the Puerco River and tributaries in Gallup, the Zuni River, Rio Pescado and Rio Nutria in New Mexico that have not been developed for urban uses, need controls to prevent unwise flood plain development. This need is particularly pronounced in St. Johns, Arizona, and Gallup and Zuni Pueblo, New Mexico.

The Soil Conservation Service (SCS), working through local conservation districts, can provide assistance to concerned property owners in planning needed flood proofing measures. Property owners can contact the local SCS field office for this assistance. SCS field offices in Arizona are located in Springerville for Apache County, Holbrook for Navajo County, and Flagstaff for Coconino County. SCS field offices are located in Gallup for McKinley County and the northwest part of Valencis County, and in Magdalena for Catron County and the southwest part of Valencia County. If investigations by the local field offices, Natural Resource or Soil Conservation Districts, or other units of government determine that the needs for nonstructural measures exceed local capabilities to plan and install the needed measures, PL-566 could possibly be used to provide planning and implementation assistance.

The SCS's Flood Plain Management Assistance Program can be used to assist local communities or units of government in collecting or furnishing information on flood hazards and flood plains. The program also can provide interpretations of flood hazard data needed in developing, revising and implementing flood plain management programs. This program is not applicable in areas already included in detailed flood hazard or flood insurance studies that have been conducted by other agencies or consultants. Those areas that have existing studies or are being studied are mentioned in the Flood Prevention Measures and Studies section of this report. Units of government that need assistance under this program should contact the local SCS office.

REFERENCES

1. Bohannan-Huston, Inc., Engineering Master Drainage Study, Pueblo of Zuni, December 1974.

2. Morrison Maierle, Inc., U.S. Department of Interior, U.S. Bureau of Indian Affairs, Navajo Water Resources Evaluation, Volume XII, Flood Plain, June 1977.

3. U.S. Army Corps of Engineers, Water Resources Development in Arizona, 1977

4. U.S. Army Corps of Engineers, Draft Review Report of Flood Control and Recreational Development, Puerco River and Tributaries, Gallup, New Mexico, June 1978.

5. U.S. Army Corps of Engineers Information Brochure-Alternative Proposals for Flood Control and Allied Purposes, Little Colorado River, Holbrook, Arizona, January 1978.

6. U.S. Department of Agriculture, Soil Conservation Service, Zuni Pueblo Watershed Work Plan, June 1975.

7. U.S. Department of Interior, Bureau of Reclamation, Zuni Safety of Dams Project, June 1974.

8. U.S. Department of Interior, Bureau of Reclamation, Draft Management Plan for Development of the Environmental Statement for the Yellow House Dam Project, 1977.

9. Telephone conversation with Mr. Ray Lenaburg, Flood Insurance Administration, San Francisco, California, August 19, 1981.